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Glass: Its Transparency and Structure

Part I. Electromagnetic Theory, Atomic Structure, Bonding, and Transparency

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TABLE OF CONTENTS

Prologue
1. Introduction
2. Electromagnetic Theory of Light
   - 2.1. Light and Electricity
   - 2.2. Electromagnetic Theory of Light
   - 2.3. Interaction of Waves and Matter
   - 2.4. The Transparency of Glass

The Basic Concept of Transparency

   - 2.5. Other Factors Must be Considered

3. Transparency Due to Relative Concentration of Matter

Transparency Due to Relative Concentration of Matter

4. Structure of Solids Related to Transparency
   - 4.1. Atomic Structure
   - 4.2. Ionic Bonded Crystals
   - 4.3. Covalent Bonded Crystals
   - 4.4. Metallic Bonded Crystals
   - 4.5. Co-ordination Theory
   - 4.6. Properties Versus Types of Bonds

Bonding in Relation to Transparency

Appendices
References

PROLOGUE

This informational summary discusses some of the "hows" and "whys" of the transparency of glass. This question of "Why is glass transparent?" has been asked of us many times. While the question sounds innocent and simple, and is usually asked by high school and college students, it cannot be answered by any one all-inclusive statement of scientific fact. A non-mathematical treatment is desirable, but in many respects unsatisfactory. A totally scientific answer requires a complete development of solid state structure—which, incidentally, is not yet fully developed and may in many respects require change as the advanced theory is being developed.

The writer certainly does not pretend to be an authority in these fields. He has attempted a qualitative, nonmathematical treatment of the subject. Obviously, this treatment is not satisfactory to the physicist nor to the person used to thinking in mathematical terms by equations. Some of the subjects introduced are still in dispute among the experts.

The writer has had the benefit of continuous contact with our own scientists and solid state specialists. He has gained much from such discussions. However, he takes the responsibility of putting a qualitative discussion down in this report with the knowledge that none of them totally agree with such a discussion. He has used their concepts and assistance in this presentation and herewith wishes to acknowledge this help.

1. INTRODUCTION

Fundamentally, the electromagnetic theory of light forms the basis for transparency and nontransparency. It, however, cannot adequately be presented by a qualitative, and nonmathematical, treatment. Such a treatment involves all the properties of matter, the theory of bonding of matter, the theory of solid state structure, the reasons for or against the electrical nature of matter, and on into the realm of the atomic nucleus and the different energy states of matter. Light is a form of energy and basically is influenced by absorption and emission of energy from different forms of matter. It is essential to realize that there is a relationship between light and electric properties and that each involves the other to some degree. Bonding of matter enters because different types of bonding give rise to different types of

electrical behavior.

Furthermore, many of the physical effects which we see must be related to sizes of objects, or particles, surface effects such as reflection, refraction and absorption, index of refraction, etc. These are all covered in a field known to the physicist as physical optics because they can be treated by straight, simple physical laws which have a simple geometric basis. Here we discuss the relative homogeneity of a volume in relation to the passage of light through it. Mixtures on a heterogeneous level give rise to light scattering and thus to opacity. The concept of what constitutes homogeneity is related to the physical wave length of the radiation (in some cases light) used for viewing.

Thus we must discuss the effects of particles and surfaces on a qualitative basis. Incidentally, the solid state physicist has only begun to study the fundamental nature of the surface in relation to the structure under the surface. This will probably be in his next realm of success.

Our presentation therefore progresses from the electromagnetic theory of light to the various types of bonding of solids, on through the physical optics involved in particles, surfaces, etc. Many of the usual, everyday experiences will illustrate these concepts, which, in a way, are interesting sidelights of the subject of transparency.

2. ELECTROMAGNETIC THEORY OF LIGHT

Light is only one segment of the entire electromagnetic radiation series. It covers that portion which gives a physiological response of vision to the eye. Light is a form of energy and as such must be treated as an electromagnetic radiation. In this respect it differs from infrared, ultraviolet, and other radiations, each of which possesses wave properties, only in that its wave length range is limited to those that produce visual effects.

In Appendix 2 we have treated briefly the subject of the electromagnetic radiations from a qualitative viewpoint. This appendix will partly bridge the gap between waves, particles, units of energy, etc. A more detailed treatment would have to be mathematical.

2.1. Light and Electricity

(Based largely on References 51 and 52) The preceding discussions and Appendix 2 point to similarities between light and electric effects. We will use three qualitative illustrations:

a. The speed of light enters into the theory of electromagnetic wave motion. When this theory is carried over to electric energy, we must use the constant of the speed of light to produce total consistency of the mathematical treatment. The wave developed by an electric spark, as well as the radio wave, travels at the speed of light.

b. Electrical conductors such as metals are opaque to light. Many electrical insulators such as glass are transparent. The presence or absence of particles *which are free to act as conductors* must be related in some fashion to light transmission. This concept is further covered later, and of course is the gist of this entire paper.

c. Light, under proper circumstances, can be affected by certain electrical or magnetic fields. This is observed by the rotation of polarized light by magnetic fields. There must, therefore, be some similarity of the fundamental natures of light and of magnetic effects.

The above facts may have to be accepted on faith, as their experimental proof or theoretical nature involves discussions much beyond our present paper.

2.2. Electromagnetic Theory of Light

(Reference 52) "Light consists of vibrating electric and magnetic fields perpendicular to each other and to the direction of travel of the wave." (Ref. 53)

The above statement could be called a descriptive theory of light. The statements under 2.1 above are merely given to prove that light and electricity have much in common. The properties of one cannot be explained without using properties of the other. In light the fundamental forces are such that electric force generates magnetic force and magnetic force generates electric. Each of these forces vibrates in planes and the corresponding opposite force is always at right angles to the other force. The direction of the associated light beam is perpendicular to both the electric and magnetic forces.

2.3. Interaction of Waves and Matter

(Reference 52) This nature of light means that light interacts with mass or matter in a fashion consistent with the electrical properties of the mass. Thus some objects are transparent or opaque because of the absence or presence (respectively) of interaction. When interaction occurs to a great degree, the light is absorbed or reflected. Thus one would expect that a mass of highly electrical nature would react greatly with light waves. Either the electric or magnetic components of light are altered or destroyed, by interaction, to a degree that the components which remain do not resemble those of the original light energy. Destruction of either the electric or magnetic vectors results in destruction of the other—as both must exist for light. Thus the light cannot pass through the mass.

This concept makes it necessary to consider the electrical nature of matter. In turn we must consider how matter is bonded together. In some cases bonding ties up the electrical nature of the mass to such an extent that it is almost inactive. This gives us our insulators, of which glass is one group. In other cases, there are so many free electrons present that can move very easily, and then we get our metals or electrical conductors. In most cases the latter are opaque, while in many cases insulators are transparent.

These arrangements of matter and the tie-up of the electrical particles with structure are discussed later in this report (see Section 4). In that section we visualize the types of matter and the relationship to transparency.

All matter has some electrical components because matter itself is constructed out of particles which exhibit electrical properties. This question of insulators and conductors is one of degree rather than one of opposite extremes.

2.4. The Transparency of Glass

When light, which is considered an electromagnetic vibration with its associated electric fields, enters a metal, it is immediately destroyed by the conduction of the metal. The waves cannot maintain themselves because their electric components are destroyed or altered by the

free electrons of the metal. The free electrons in the metal structure can migrate easily and neutralize the potential of the light electric components. The result is absorption or reflection. Put in another fashion, metals cannot support an electric potential—they tend to immediately equalize such potential by free electron conduction.

Glasses, on the other hand—see later under Section 10—do not have free electrons because of the nature of their bonding. While electrons are, of course, present, they are bound within the solid structure to ions or atoms. They cannot move freely and do not therefore equalize an electric current. While an electric potential, as well as light, can cause these electrons to move slightly, they do not traverse the structure. They return to their original location when the potential is removed. Displacement of electrons in a glass is somewhat analogous to the compression and release of a spring, since the parts return to their original position. Thus glass as an electrical insulator supports electric potential—for instance, 110 volts on one side to ground or zero voltage on the opposite side.

The fact of support of a potential allows the electrical aspects of light to pass through it unaltered. Thus the object is transparent.

The Basic Concept of Transparency

The electrical nature of glass, which lacks electronic conductivity, is such that it can support electric potential without free electron travel. Because the electrons are tightly held to positions within the structure, by the type of bonding in glass, they cannot move great distances and neutralize the electrical aspects of light. Basically there are no interactions of permanent nature between the electric components of the mass and the light. Thus alteration of light is minor and the glass is transparent.

2.5 Other Factors must be Considered

The above theory on nature of mass, energy and light is well accepted. Mathematical proof, though omitted here, is considered complete. Fundamentally, the electromagnetic theory of light assumes some degree of homogeneity of the body involved. When the mass becomes a visible mixture and thus is not homogeneous, we get into effects on light which are considered from the viewpoint of plain geometric optics. For instance, glass is transparent, but by means of its surface contours we produce lenses which focus light; or powdered glass mixed with air is opaque because of light scattering. These are effects which are related to the surface properties of refraction and reflection. See Sections 6, 7 and 8.

3. TRANSPARENCY DUE TO RELATIVE CONCENTRATION OF MATTER

As we shall show later, solids are generally considered bonded together with contact between the building units or atoms, etc. While all matter is largely open space (see later under Section 4.1), when we get down to discussing the atom, we consider that atoms and molecules have "diameters" which encompass the outermost electrons of the structure and are determined by summating the adjacent distances between centers of the structure. In liquids we shall also note that these atomic distances are a little greater than in the corresponding solid. Most materials expand when they pass from solid to liquid, but only enough to provide 10 per cent or so greater atomic distances.

However, when a liquid forms a gas by evaporation, we get a volume of gas which assumes the shape of the container. The expansion may be several-fold, so that the atoms or molecules are no longer in direct and continuous contact. We have, relatively, a volume with a great distance between particles.

Carrying the concept further, we progress to a partial vacuum. A complete vacuum might be described as the absence of all matter. Such is, of course, not possible.

A true absence of matter would, by the electromagnetic theory of light, be transparent. It would possess no electrical properties to interact with the light. Of course, a true vacuum is never attained because there are always present a rather large number of atoms or molecules in the best attainable vacuum. When we progress from a true vacuum to a gaseous volume, we find that the gas is also transparent *due essentially to the absence of sufficient matter* to give interaction with light waves. There are many particles of matter—that is, atoms or molecules—in a gas. For instance, one liter of air at room temperature evacuated to .0001 mm. of mercury pressure contains 3.24×10^{15} molecules[1]. You are all acquainted with the fact that one mole of any gaseous substance contains the same number of molecules. This number is known as the Avogadro number, which is 6×10^{23} molecules per mole. Since a gram-molecule-weight of any gas at standard temperature and pressure occupies 22.4 liters, it is obvious that one liter of a gas at standard temperature and pressure contains $6 \times 10^{23}/22.4$, or 27×10^{21} molecules. In a gas the molecules are continually in motion and in impact against one another. This impact is what produces the gaseous pressure.

(Reference 30) For instance, in nitrogen at 25° C. (and one atmosphere) there are approximately 2.9×10^{23} collisions per sq. cm. per second against the wall of the container. There are 7.8×10^{28} collisions per cu. cm. per second between molecules. The molecules are traveling at a mean rate of approximately 50,000 cm. per second, but they are only traveling, in the case of nitrogen, approximately .0000075 cm. between collisions. The average space between gas molecules would be approximately 70×10^{-8} cm. if they all were temporarily held still. In the case of gases the molecules have diameters ranging from about 2 to 5×10^{-8} cm. Thus the open space between molecules is many times the size of a molecule. While we state that a gas is transparent because of the absence of matter and because of the distance between the particles, it is obvious that we are talking on a relative basis in relation to solids.

There are some cases of gases which show slight color. In these cases the vibration of the molecule has a frequency of near that of light and thus absorbs portions of the light spectrum. This gives a transparent color (see Section 5).

1 See Appendix 1 for use of units.

Transparency Due to Relative Concentration of Matter

Most gaseous volumes and partial vacuums are transparent because of absence of enough matter to give interaction with the light waves. Because of the great distance between molecules, the direction and properties of light waves go unaltered. Neither the particle size nor the electrical effects are big enough to alter the light. This covers transparency of gases.

4. STRUCTURE OF SOLIDS RELATED TO TRANSPARENCY

The presence or absence of free-moving electrons in a solid has been shown to be a factor in transparency. In this section we shall present the story of atomic structure and atomic bonding. General properties of solids in relation to type of bonding will show that the influence of bonding is a fundamental one. This is the reason for so much work being done by industry in fundamental science. When we understand these principles, we are usually able to do something which makes the material more useful.

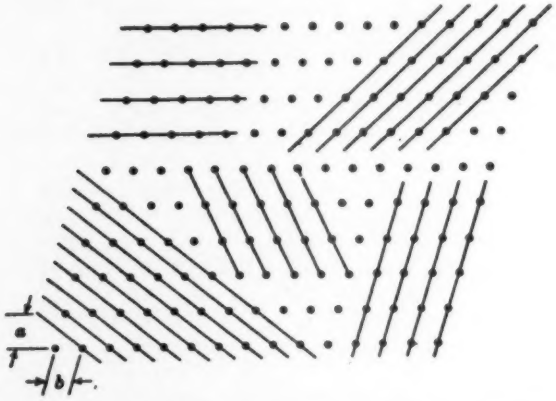


Fig. 1. Planes through lattice points of a crystal, showing constantly repeated structure. (from Ref. 30)

From *Physical Chemistry*, F. Daniels and R. A. Alberty, John Wiley & Sons, Inc., (1955).

In contrast with a gas or a liquid, solids possess a definite form and definite surfaces. They represent the most dense state of matter. Solids may be crystalline, amorphous, colloidal, vitreous, or aggregate in nature. Some of these represent well accepted views, while others still represent argument. Solids can be transparent, colored or opaque, conductors or nonconductors, single crystalline or multiple crystalline, isotropic or nonisotropic, etc.

Fundamentally crystals are solids in which the atoms are arranged in some definite order which is constantly repeated (Fig. 1). The smallest unit which can be constantly repeated to give a crystal is called the "unit cell." There are several types of crystalline solids, some of which contains electrons which are very tightly held within the crystal structure and others of which contain electrons which are almost totally free to move. In between these two extremes, of course, there are imperfect situations which have intermediate properties.

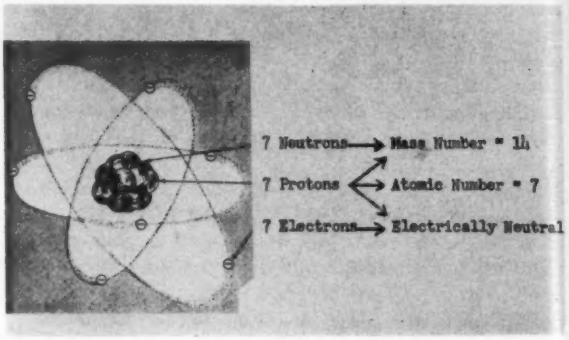


Fig. 2. The structure of the nitrogen atom, showing atomic number, mass number, and electrons. (adapted from Ref. 21)

From "The Physics of Nuclear Power", W. E. Schoupp, *Westinghouse Engineer, 14* (1954).

4.1. Atomic Structure

(Based largely on References 1, 2 and 30) In order to understand some of the types of bonding which will be described below, it is important to have at least a preliminary view of the structure of the atom. The atom's structure is, of course, different for each of the elements, but basically it consists of a nucleus which carries the major mass of the atom surrounded by electrons in different electron orbits and at different distances from the nucleus. The electrons are known to have almost negligible mass and can therefore move very rapidly. The nucleus carries different weights from that of hydrogen to that of uranium (and higher). Except for hydrogen, the nucleus is made up of a combination of protons which carry the positive charge and neutrons which are of almost identical weight to a proton, but do not carry any charge. The atomic number of the element is determined by the number of protons or positive charge, while the atomic mass or weight is determined by the sum of the number of protons and neutrons. There is always an excess positive charge in the nucleus and therefore, in order for the atom to be neutral, there must be sufficient electrons in orbits around the nucleus to neutralize this positive charge. For instance, the nitrogen (see Fig. 2) atom contains 7 protons, 7 neutrons, and 7 electrons. The 7 protons carry the positive charges, the 7 electrons carry the negative charges. The 7 protons determine the atomic number of 7 and the sum of the 7 protons and 7 neutrons gives 14, which is the atomic

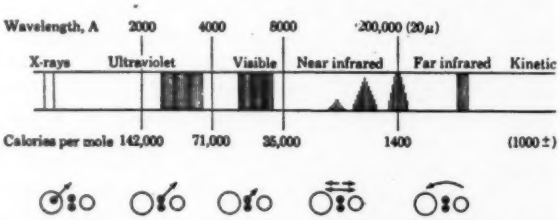


Fig. 3. Schematic representation of different types of spectra, showing the wave-length ranges and the energy ranges in which they occur, and the corresponding electronic, vibrational, and rotational motions. The black dots represent electrons and the larger circles represent atoms in the molecule. (Ref. 30)

From *Physical Chemistry*, F. Daniels and R. A. Alberty, John Wiley & Sons, Inc., (1955).

weight or mass number. Electrons which are nearer the nucleus are held more firmly and the accepted theory now provides for a definite number of electrons in each orbit as we progress away from the nucleus. The electron orbits, beginning with that nearest the nucleus, are known as K, L, M, N, O, P, Q. When the K orbit is filled, it carries two electrons; when the L orbit is filled, it carries 8; M carries 18; N carries 32; O carries 32; P carries 18; and Q carries 8. The incompleteness of the outer orbits for any particular element is an indication of electropositivity [1] or electronegativity[2]. The unit of electronic valence is one outer electron. Eight is the goal of valence, for the atom seeks an octet or cubic outer sheath. The number of outer electrons of an atom is the positive electronic valence; the number it lacks of 8 is its negative valence. Each atom has thus both positive and negative valence and their sum is 8.

By sharing electrons in lots of 2 (which pair corresponds to the two corners, or one edge, of the cube), atoms may build molecules wherever the combination gives an octet or cubic sheath to each atom. This is a covalent type of structure (see Section 4.3).

A normal atom has no ionic valence, since it has an equal number of positive and of negative charges. The unit of ionic valence is one excess positive or negative charge in an unbalanced or charged atom. Such a charged atom is called an ion and may have a stable outer octet of electrons. It unites with other atoms by electrostatic attraction for another ionized atom of opposite electrical charge. This is the ionic type of structure (see Section 4.2).

The positive ionic valence is the excess positive charge left when an atom loses negative electrons. The negative ionic valence is the excess negative charge of an atom gained by adding negative electrons. The gain or loss of electrons makes the atom an ion and the number gained or lost is the number of charges or the ionic valence.

In this atomic picture we have electrons circling around the nucleus in certain bands or areas. As long as an electron continues to circle within an orbit, it does not use any energy in this motion. Energy is absorbed or emitted when an electron leaves or enters an orbit. That is, each orbit represents a different energy level. Each energy level change also represents a corresponding frequency or wave length. Light absorption in the visible generally involves the displacement of an electron within a molecule. See the middle portion of Fig. 3. Some elements in Group VIII and adjacent portions of the atomic table (Table 1) are generally classified as transitional elements. These generally produce color when in solutions or in glasses. Please refer to Section 5.

4.2. Ionic Bonded Crystals

(References 10, 23, and 30) A perfect single crystal of a material which is bonded *ionically* with colorless ions will be transparent. This is the case which is common for a material like sodium chloride, where an electronegative and an electropositive atom enter together in an ionic or electrical fashion and completely neutralize each other in the final crystal. (See Fig. 4) Elements in Groups I to IV of the periodic table

1 Base formers
2 Acid formers

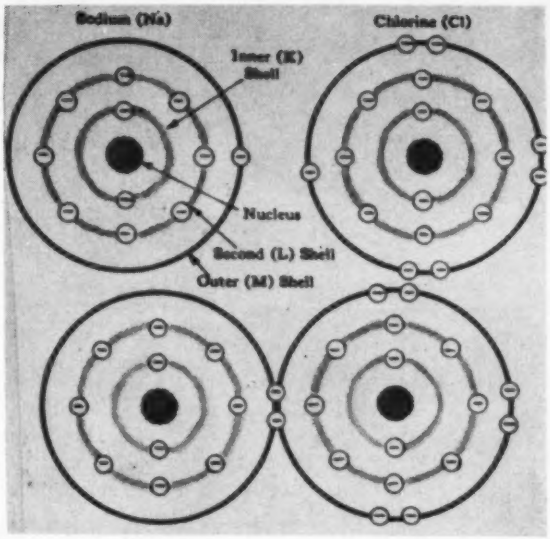


Fig. 4. Ionic bonding. In the formation of a sodium-chloride molecule, the outer-shell electron of sodium is in effect transferred to the outer shell of the chlorine atom. Thus the bond is essentially electrostatic between positive and negative ions. This type of bonding is called "ionic." (Ref. 23)

From "Fundamentals of Electrical Insulators", J. Swiss and T. W. Dakin, *Westinghouse Engineer, 14* (1954).

(Table 1) contain only a few electrons in their outer atomic shell and have a strong tendency to form a stable outer shell by losing these electrons. Elements in Groups V to VIII of the periodic table have a strong tendency to form a stable outer electron shell by completing it. Thus sodium and chlorine go together and transfer electrons from the sodium atoms to the chlorine atoms to form the crystal sodium chloride in an ionic fashion. Such crystals, when they are dry and in the solid state, are excellent insulators because the electrons are tightly held and because the ions are immobile. The structure which

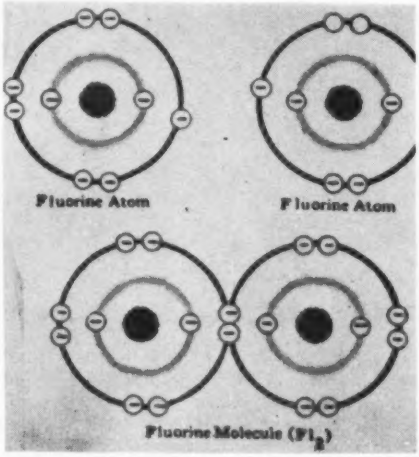


Fig. 5. Covalent bonding. This example of covalent bonding shows two atoms of fluorine combined to form a fluorine molecule. Each atom has seven outer-shell electrons; they share two between them, thus giving the effect of completing both outer shells. (Ref. 23)

From "Fundamentals of Electrical Insulators", J. Swiss and T. W. Dakin, *Westinghouse Engineer, 14* (1954).

Table 1

Periodic Table of the Elements

IA	IIA						1 H 1.0080					IIIA	IVA	VA	VIA	VIIA	2 He 4.003
3 Li 6.940	4 Be 9.013											5 B 10.82	6 C 12.010	7 N 14.008	8 O 16.0000	9 F 19.00	10 Ne 20.183
11 Na 22.997	12 Mg 24.32	IIIB	IVB	VB	VIB	VIIB	——VIII——			IB	IIB	13 Al 26.98	14 Si 28.09	15 P 30.975	16 S 32.066	17 Cl 35.457	18 A 39.944
19 K 39.100	20 Ca 40.08	21 Sc 44.96	22 Ti 47.90	23 V 50.95	24 Cr 52.01	25 Mn 54.93	26 Fe 55.85	27 Co 58.94	28 Ni 58.69	29 Cu 63.54	30 Zn 65.38	31 Ga 69.72	32 Ge 72.60	33 As 74.91	34 Se 78.96	35 Br 79.916	36 Kr 83.8
37 Rb 85.48	38 Sr 87.63	39 Y 88.92	40 Zr 91.22	41 Nb 92.91	42 Mo 95.95	43 Tc (99)	44 Ru 101.7	45 Rh 102.91	46 Pd 106.7	47 Ag 107.880	48 Cd 112.41	49 In 114.76	50 Sn 118.70	51 Sb 121.76	52 Te 127.61	53 I 126.91	54 Xe 131.3
55 Cs 132.91	56 Ba 137.36	57–71 Rare Earths	72 Hf 178.6	73 Ta 180.88	74 W 183.92	75 Re 186.31	76 Os 190.2	77 Ir 193.1	78 Pt 195.23	79 Au 197.2	80 Hg 200.61	81 Tl 204.39	82 Pb 207.21	83 Bi 209.00	84 Po (210)	85 At (210)	86 Rn 22
87 Fr (223)	88 Ra 226.05	89– Acti- nides															

57 La 138.92	58 Ce 140.13	59 Pr 140.92	60 Nd 144.27	61 Pm (145)	62 Sm 150.43	63 Eu 152.0	64 Gd 156.9	65 Tb 159.2	66 Dy 162.46	67 Ho 164.94	68 Er 167.2	69 Tm 169.4	70 Yb 173.04	71 Lu 174.99	Rare earths (Lanthanide series)

89 Ac (227)	90 Th 232.12	91 Pa 231	92 U 238.07	93 Np (237)	94 Pu (242)	95 Am (243)	96 Cm (245)	97 Bk (249)	98 Cf (249)	99 E (253)	100 Fm (254)	101 Mv (256)	Actinide series

is attained will be continually repeated to form large crystals. As long as we have a perfect single crystal, we will have transparency, and this transparency depends upon the fact that there are no free electrons to absorb radiation. In recent years perfect single crystals are being grown for optical purposes. We refer, for instance, to Al_2O_3 (white sapphire) and other types of crystals.

In a large mass it is difficult to grow single crystals because crystalization starts at several different points simultaneously and each of these results in single crystal growth until they interfere with each other. Similarly, impurities in the mass, such as gases and different elements, will cause imperfections. Such masses of crystals are sometimes called aggregates. An aggregate may be made of a group of small crystals of like nature, or it may be made of a group of crystals of differing nature

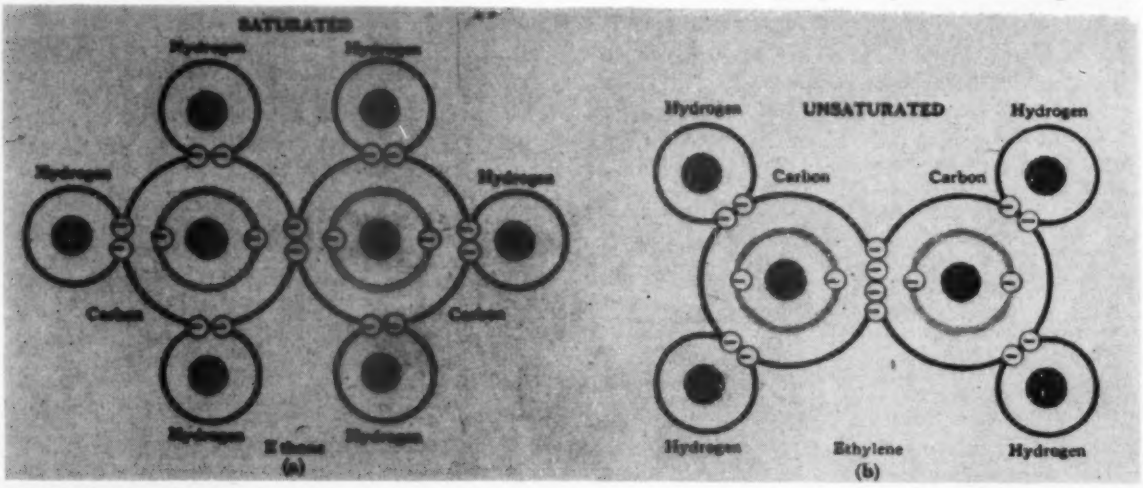


Fig. 6. Covalent bonding in carbon chains showing saturated and unsaturated compounds. Unsaturated groups are those in which bonding is accomplished by two or three pairs of electrons, as in ethylene; this, in effect, allows further combination with other groups, since one pair of electrons can be used in some other combination. In saturated groupings, such as ethane, the combination is essentially complete, since no electron pairs are left over. (Ref. 23)

From "Fundamentals of Electrical Insulators", J. Swiss and T. W. Dakin, *Westinghouse Engineer, 14* (1954).

Table 2

Properties vs. Types of Bonds

	Ionic	Covalent	Metallic	Van der Waal's
Mechanism of Bond	Metals lose electrons; non-metals gain electrons; electrical neutrality	Pairs of electrons shared by two atoms; electrical neutrality	Only positive ions, with free electron cloud	Nonchemical, polar, mass low
Types of Atoms Bonded	Opposite polarity	Same polarity	Same energy level	Stable gaseous
Mechanical Properties	Strong, hard	Strong, hard	Variable	Weak, soft
Thermal Expansion	Low	Low	—	High
Melting Point	High	High	Variable	Low
Thermal Conductivity	—	—	High	Low
Electrical Conductivity	Nonconducting	Nonconducting	High	Nonconducting
Optical	Variable	High index	Opaque	Transparent
Structural	High co-ordination	Low co-ordination	Very high co-ordination	—
Typical Examples	NaCl	Organic solids, carbon, silicon, oxygen	Metals	Noble gases, some organics

if the mass from which the crystals grew happened to have variations in composition. When a crystal surface occurs it gives the same effect as we have discussed below (Sections 6 and 7). It also results in a different index of refraction, so that we have light being bent and returned to the viewer. Thus most crystal materials are not transparent because of different orientation of crystals, crystal phases, imperfections, etc. Crystal faces which reach about 5000-10000 Å or so begin to become visible, without magnification, as light spots.

4.3. Covalent Bonded Crystals

(References 10, 23, and 30) A second main type of bonding of crystals is known as *covalent*. When a chemical bond occurs between two atoms that are not of widely differing electronegativity, we produce a crystal in which valence electrons are shared by each neighbor. The extreme case of covalent bond occurs when two atoms of the same element are involved. (See Fig. 5) In the illustration two atoms of fluorine, each having seven outer shell electrons, share two electrons between them and give the effect of completing the outer electron shells of each.

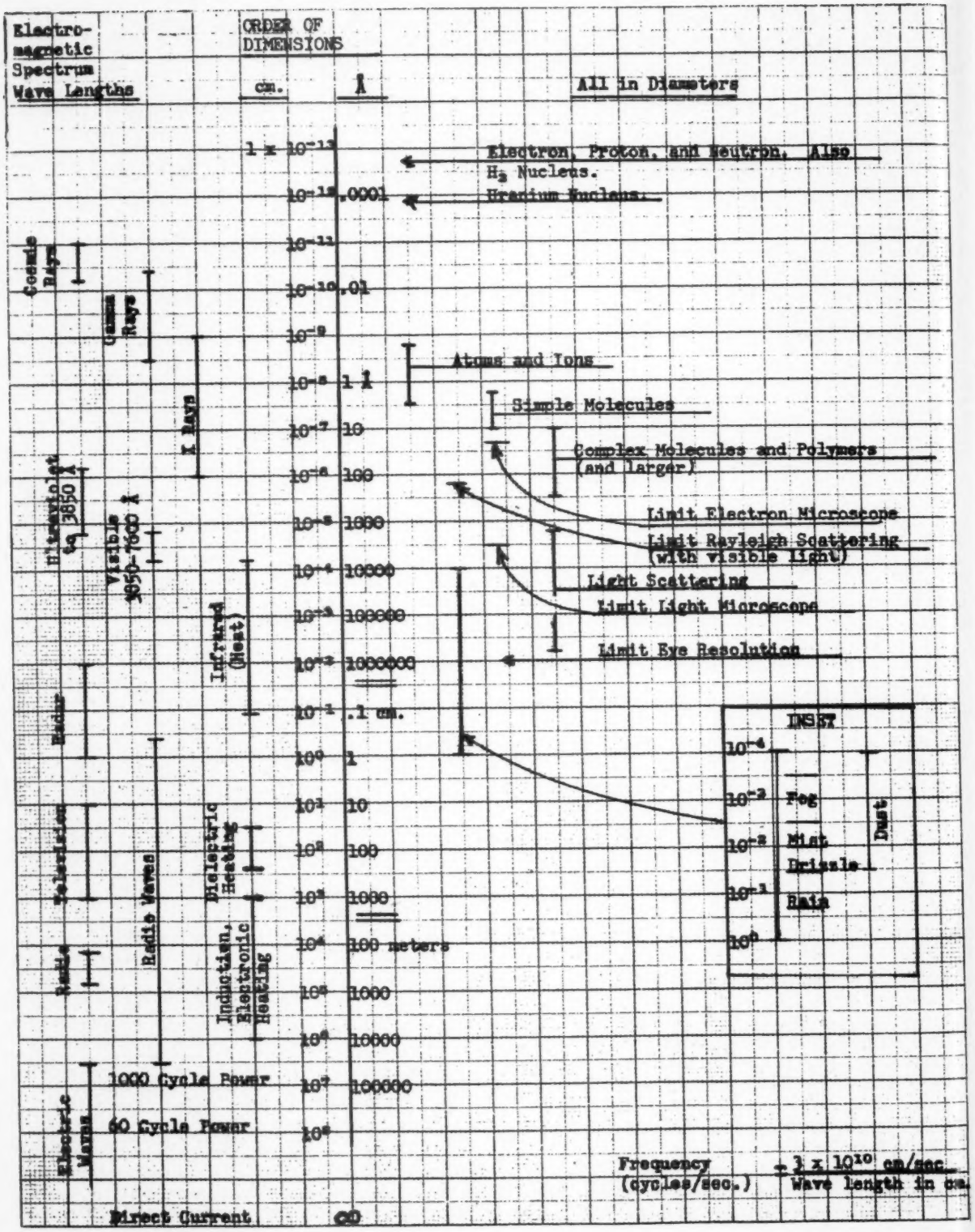
Atoms in Groups IV and V of the periodic table tend to form covalent bonds with other elements or with themselves. They are neither strongly electropositive nor strongly electronegative. Carbon is one of the most important of these elements. It can form chains with itself. These chains can be saturated or unsaturated (Fig. 6). Many of these compounds are good insulators because there are no free electrons and the molecule is electrically balanced. In fact, they do not form any ions such as ionic bonded materials form when in solution. Even when in liquid form, they are insulators.

4.4. Metallic Bonded Crystals

(References 10, 22, 30, and 49) A third major type of bonding is that known as *metallic bonding*. We all know that metals in crystalline form are very good conductors and metallic bonding involves a situation where there is a cohesion between metal atoms, which cohesion does not greatly involve the electrons in the outermost orbits of each atom. The positive ions are held together by a cloud of mobile, free electrons not localized to any particular lattice site. These electrons become relatively free and by jumping from one position to another cause metallic conduction. The illustration of metallic bonding is given in Fig. 7. In a cu.cm. of metal there are approximately 10^{22} free electrons. These electrons are no longer associated with any specific atom. The resistivity of the

Table 3

Wave Lengths, Particle Sizes, and Other Dimensions (Ref. 30)



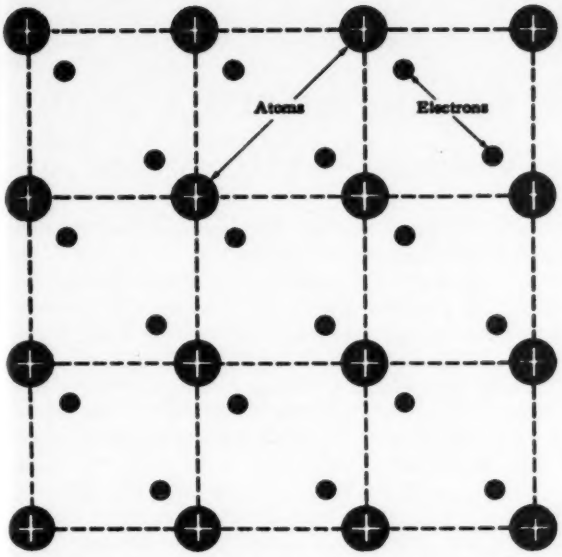


Fig. 7. Metallic bonding. In a metal, valence electrons are relatively free and not localized to any particular lattice site. They may jump from one site to another, thus giving metallic conduction. (Ref. 22)

From "Semi-Conductors, Their Characteristics and Principles" T. R. Lawson, *Westinghouse Engineer, 14* (1954).

metal is largely determined by the degree of perfection of the lattice, and if the lattice is perfect and is at absolute zero, it theoretically has zero resistivity.

Considering transparency, however, it is these free electrons in the metal which give it its nontransparency. There are so many free electrons present that they continually interact and deflect any eletromagnetic wave which enters the metal. We must therefore state a concept which is important for the attainment of transparency in any body. *This concept is that an electromagnetic disturbance within a vacuum or an insulating dielectric should be propagated indefinitely.* Absorption of waves occurs when the medium has some degree of electrical conductivity. For instance, the car radio loses its volume as you drive under the steel structure of a bridge. This simple illustration shows that the metallic conduction properties of the steel structure have an effect upon the electromagnetic wave which the radio uses. These effects are very predominant when there are large numbers of free electrons.

4.5. Co-ordination Theory

The above structural types of bonding stem from fundamental atomic interactions. Another theory, however, covers just what is possible from an arrangement viewpoint when we consider arrangement in volumes. This theory is known as the co-ordination theory.

Anions (with negative excess charge) are generally larger (Fig. 8) than cations (with positive charge). Thus it is to be expected that structure is formed by regular groupings of anions closely packed around each cation.

The number of anions surrounding any cation is known as the co-ordination number and is dependent upon the respective ionic radii.

From strictly geometric considerations it is possible to calculate this co-ordination number by relating it to the ratio of cation and anion radii. The following table gives the general picture: (Reference 10)

Co-ordination Number of Cation	Radius Ratio $\frac{\text{r cation}}{\text{r anion}}$	Typical Glass Ions
3	.155 - .225	Boron
4	.225 - .414	Si, Al
5	.414 - .732	Al, Mg
8	.723 -1.)	
12	1 -1)	Na, K, Ca

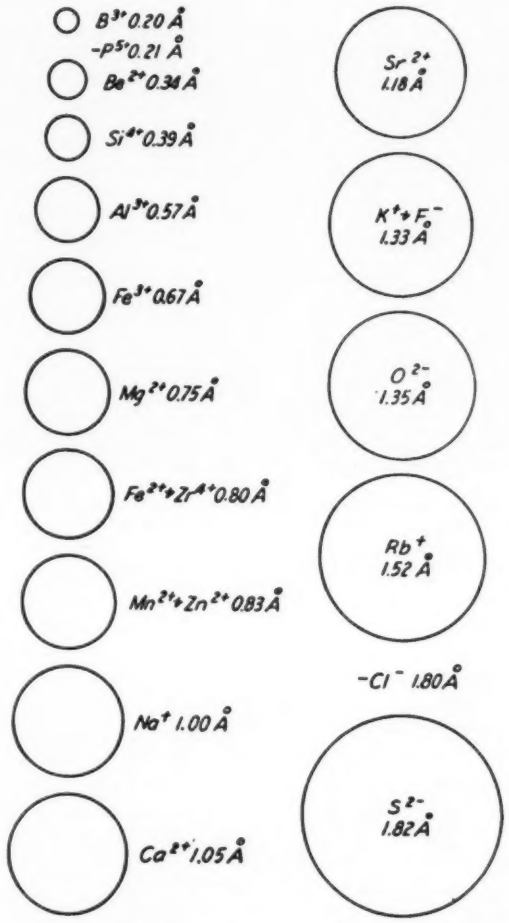


Fig. 8. The ionic radii of elements drawn to scale. This shows large anions (negatively charged), particularly oxygen, in relation to smaller, positively charged cations. (Ref. 12)

Although SiO_2 is the basis for glass, the basic structural unit is SiO_4 in tetrahedral formation (Si center and O at each of four corners). (See Fig. 9.) The radius ratio for silicon to oxygen is 0.29.

Thus, we not only have valence and electrical requirements, but particle packing is very dominant. Both must be satisfied.

(*Continued on page* 110)

Littleton Receives Toledo Award

Symposium on Glass Melting is Held in Conjunction with Award Presentation.

• MORE THAN 300 MEMBERS and guests of the Northwestern Ohio Section of the American Ceramic Society gathered in the Toledo Club at Toledo, Ohio on January 20 to honor Dr. Jesse T. Littleton, retired Vice-President of Research, Corning Glass Works, for his contributions and leadership in the science of glass, especially in the field of physics.

Fred L. Bishop presents the Toledo Award to J. T. Littleton (at right).

The occasion was the presentation of the third Toledo Glass and Ceramic Award by the Northwestern Ohio Section. The Award Dinner culminated an all-day program which began with registration at the Hospitality Headquarters, in the Hillcrest Hotel and included a luncheon, and symposium on "Glass Melting". A program of interest to the ladies was conducted simultaneously with Mrs. Fred Bishop and Mrs. Ralph Day in charge.

The award object is in the form of a lead glass vase made by the craftsmen of the United States Glass Co., Tiffin, Ohio to a design originated by Edwin W. Fuerst, of Waterville, Ohio, with Blake-More Godwin, Director of the Toledo Museum of Art, as consultant.

The citation as read by Dr. Fred L. Bishop, chairman of the award committee, in presenting the vase, was as follows:

"Jesse T. Littleton, in recognition of your lifetime devotion to the science of glass, your leadership in formulating and measuring its physical properties; your authoritative book on the Electrical Properties of Glass and your authorship of many other scientific papers and patents in the broad field of your career;

"Also for your personal leadership of and service to your associates as exemplified by your term of office as President of the American Ceramic Society and by your encouraging technical meetings of good fellowship and thereby helping to start our very important Fall Meetings of the Glass Division;

"For these amiable accomplishments and qualities, we, of the Northwestern Ohio Section of the American Ceramic Society present you with this, the 1958 Toledo Glass and Ceramic Award."

Toastmaster Ralph B. Vogel, chairman of the Northwestern Ohio Section, spoke briefly on the purpose of the award and then presented a short biographical sketch of Dr. Littleton.

Dr. Eugene C. Sullivan, past president, now honorary chairman of Corning's board of directors and for whom Corning has just recently named its new laboratory and development buildings, paid personal tribute to Dr. Littleton, and outlined some of the highlights of his life and work.

He emphasized the thorough training and originality which characterize Dr. Littleton, and his leadership which has inspired so many others into fruitful fields of endeavors. Dr. Littleton has been either directly or indirectly responsible for initiating the development of such products as glass ovenware, tempered glass, glass with electrically conductive coating, glass made by centrifugal casting, photosensitive glass, chemically machined glass, and the latest group of products known as Pyrocerams. Dr. Sullivan dwelled on the physical robustness with which J. T., as he is affectionately called by his associates, tackled not only his work, but his leisure time, many hours of which were spent hunting and fishing.

Howard R. Lillie, past president of the American Ceramic Society and lifetime associate of the awardee, spoke for Dr. Littleton's many friends by pinning on him a large placard on which the initials J. T. were expanded to read "Just Tops".

In responding to the many tributes to his life and achievements, Dr. Littleton gave a great deal of praise to the men with whom he had dealt down through the years and to Corning management who exercised the utmost confidence in him.

Departing from the subject of glass, a colored movie film was shown which presented some excellent shots of large Alaskan brown bear in their natural habitat. These films, which were photographed by Dr. Littleton's brother Wilbur, depicted the rugged, unspoiled setting in which these animals live on Admiralty Island off southeast Alaska.

In the earlier part of the program, Dr. Vogel had introduced Charles S. Pearce, general secretary of the American Ceramic Society. Mr. Pearce pointed out that in addition to the awardee, two other past presidents of the Society were present, namely Francis C. Flint and Howard R. Lillie, whom he introduced to the group.

He also introduced the current president of the Society, John F. McMahon, and the president-elect, R. S. Bradley.

President McMahon presented greetings to the group, and extended congratulations on behalf of the American Ceramic Society. Dr. Vogel also praised Delos M. Palmer for his performance as chairman of general arrangements in making the day-long program a success.

About 150 people attended the symposium on "Glass Melting" held in the afternoon. Almost half of this number came from outside of the Northwestern Ohio section area.

Professor Fay V. Tooley of the University of Illinois, moderator of the symposium welcomed the group and introduced the panel consisting of seven members, Dr. James M. Poole, Brockway Glass Company; Dr. Charles A. Bradley, Corning Glass Works; Aaron K. Lyle, Emhart Manufacturing Company; Fred R. Motsch, Foster-Forbes Glass Company; Dr. Roy S. Arrandale, Thatcher Glass Manufacturing Company; Henry E. Walker, Harding Glass Company, and Ralph Brannan, Owens-Corning Fiberglas Corporation, each highly experienced in the field of glass melting.

Dr. Tooley suggested that the subject of "Glass Melting" was a fitting one to dwell on since Dr. Littleton himself had for so many years taken a great interest in the more practical aspects of glass technology.

The specific question posed for the discussion was: "What are the limiting conditions for preparation of glass which is adequate for a forming process?" Each member of the panel was allowed 10 to 15 minutes to discuss the question drawing from his own experiences and imagination and presenting the visionary, the speculative, occasionally reaching into the sublime and the ridiculous. After seven separate presentations were given, the discussion was thrown open to all for an hour of questions and answers. This "Blue Sky" type of session succeeded in arousing the imagination of even the most conservative members of the group toward considering the possibilities, and problems which lie ahead in the realm of glass making.

Considerable emphasis was given by the panel to the problem of obtaining a greater degree of control over the conditions which surround a glass furnace. It was pointed out that many important furnace conditions may still not have been recognized, and that many of those which are now recognized have not yet been adequately measured. Specific examples were cited where small furnaces which are "shut-down" periodically can not be returned to the condition where they produce the same quality glass merely by reproducing the temperature of the glass. In these instances it is found necessary to raise or lower the temperature of the glass to compensate for the changes that have occurred in the other conditions surrounding the furnace. More work was advocated in the field of designing and developing much more sensitive means of detecting and recording small changes in furnace conditions in the hope that the melting operation may become more fully automatic. Also emphasized was the need for obtaining, and correlating data on furnace conditions and existing glass quality, rapidly enough to make the information useful in control work.

The first three recipients of the Toledo Award: (from left) Francis C. Flint, Donald E. Sharp, and Jesse T. Littleton.

From left, William C. Taylor, Eugene C. Sullivan, and Games Slayter at the Award Dinner.

Methods of accomplishing controlled mixing of the melt were discussed. It was agreed that natural mixing of the melt was not always completely effectual, but it was pointed out that mechanical mixing unless properly controlled would probably speed the solution of refractories. Greater control of furnace atmospheres was advocated in order to regulate the quantity and nature of gases dissolved in the glass. Also a more thorough study of the conditions needed to minimize the number and size of seeds in the fining process was recommended. Most of the inhomogeneity in glass was attributed directly to the lack of proper furnace controls.

It was suggested that the glass melting operation today is just too large and complicated to be accomplished in one furnace unit. New types of furnaces were suggested, each designed to accomplish a specific portion of the glass making operation such as heating the batch, melting the batch, and fining the glass. By making the glass in separate steps, it was hoped that the control problem would be greatly simplified. Also, it was indicated that the furnace could be designed to minimize or eliminate such problems as batch carry-over and volatilization of the melt, and that more extensive use of platinum could be made in controlling the final stages of the glass making operation. A study of new types of furnaces designed so that they lend themselves more easily to various types of glass making machines was also advocated.

More complete studies of the melting rates of glass batch materials were recommended by the group. Many ideas were presented by the panel and from the floor suggesting more efficient methods of transferring heat to the batch. Also, new sources of energy and methods of applying this energy to melt glass were discussed. The pre-heating of basic batch compositions at lower temperatures, where radiation losses are lower, combined with shorter periods of high temperature melting were suggested as a possible means of conserving heat. The advantages of directly melting small pellets of batch in a flame rather than by conventional methods was mentioned but described to be uneconomical. The problems involved in trying to use nuclear energy and solar energy efficiently in glass melting operations were also discussed by some members of the panel.

Glass homogeneity was definitely associated with homogeneity of batch by one panel member. Suggested was the possibility that mixed batch materials might one day be purchased directly from the present suppliers of individual raw materials and that batch uniformity would thus be guaranteed by the vendor.

The importance of a more complete investigation of the effects of adding minor and trace constituents to glass batches, and further study into the physics involved in such additions was emphasized. In connection with glass batches, it was suggested that the lack of continuing availability of certain glass making ingredients might impose certain limits on future glass compositions.

The pros and cons of using refractories which resist attack, but produce stones and cords which dissolve very slowly in the glass melt, or using refractories more nearly like the batch in composition and which dissolve more readily in the melt were presented. It was agreed that better refractories would always be welcomed, but that more complete studies of refractory solution would be helpful in determining where in the furnace, and under what conditions the refractories now available are best suited.

The increasing demands of the public for higher quality glass were also pointed out by the panel. Examples where quality demands on the glass have pressed the need for closer furnace control and study of glass making conditions were cited. One panel member stated, for example, the tighter restrictions on the number of allowable defects permitted in television tube face plates. It was pointed out that the presence of even one of these defects might be sufficient to cause a failure in the production of glass fibers. Demands in quality along the search for greater efficiency were given as the prime reasons for the growing interest in the technology of glass melting.

Dr. Tooley in closing praised the panel for the constructive manner in which they presented their views and thanked the audience for their active participation in the symposium. He requested the press not to be too specific in writing up the details in order that the intended spirit of the symposium might be preserved.

• William T. Lowe, known throughout the glass industry as "Dean of Traffic" retires this month as general traffic manager of the American Window Glass Company, following 54 years of service.

L.O.F. FORMS ENGINEERING FUELS-INSTRUMENT GROUP

A new instrumentation and fuels group in the engineering department of Libbey-Owens-Ford Glass Company has been established to improve technical service to company glass plants, it was announced by Roy A. Nyquist, director of engineering.

James A. Palmer, who has supervised the former fuels group, will have charge of the new combined group. H. W. Grell, Jr., is being transferred from the structural section to serve as Mr. Palmer's assistant in the new group.

All activities of the instrumentation and fuels group will be under direction of R. E. Warren, chief of the general engineering services division, and also chief electrical engineer.

Mr. Palmer was graduated from University of Michigan in 1948 as a chemical engineer and has also done graduate work in industrial management at the University of Toledo. He joined LOF in 1954 and has had considerable experience in fields of fuels, instrumentation, and water treatment and supply.

Mr. Grell is a graduate of Lehigh University receiving his mechanical engineering and civil engineering degrees in 1950. He joined LOF in 1955 and has had several important assignments including resident engineer at Ottawa, Ill., during construction of two new grinding and polishing lines. He was recently registered as a civil engineer by Ohio.

A. J. COHEN NAMED HEAD OF GLASS FELLOWSHIP

Pittsburgh Plate Glass Company has announced that Dr. Alvin J. Cohen has been named head of the glass fellowship sponsored by the company at Mellon Institute. Dr. Cohen succeeds Dr. T. Harrison Davies who recently was named director of research of Mellon Institute.

Dr. Cohen became a fellow in the Pittsburgh Plate sponsored fellowship in 1953 and has since been engaged in intensive research in glass structure, formation of color centers in silica systems by high energy radiation and other allied glass research areas. Dr. Cohen was graduated from the University of Florida with a bachelor of science degree in chemistry and earned a Ph.D. in inorganic chemistry from the University of Illinois.

FIBERGLAS ADDITIONS NEAR COMPLETION

New additions to the Owens-Corning Fiberglas Corporation's plant at Anderson, South Carolina are nearing completion according to the Daniel Construction Company of Greenville, S.C. The new structures included in the program will add to the flexibility and productivity of the large operation.

An addition to the fabrication building has been completed as well as a marble forming building, spray pond, and pump house. The sludge drying beds and sand filters are also finished, as are the settling and digester tanks. The marble furnace building is nearing completion and has been made weather tight. Work on the glass furnace is 50 per cent complete. The Daniel Construction Company built the original facilities at Anderson and has since made additions and improvements.

Spectra of Simple Glasses in the Infrared Range and their Relations to the Structure of Glass

By V. A. FLORINSKAYA and R. S. PECHENKINA
Free Translation of the Russian Original Text
By WILHELM EITEL, Institute of Silicate Research
University of Toledo, Toledo, Ohio

PART II

THE STRUCTURE OF LEAD GLASSES

• BEFORE SPEAKING OF the structure of glasses it must be remarked that the existing equilibrium diagrams of the simplest systems, which are only based on data of crystal-optical analysis, must be approximations. They do not indicate all the silicates which do really exist in the given system and may participate in the formation of the glass structure. It was shown by comparing the spectra of devitrified two-component lead silicate glasses with lead oxide contents varying between 23 to 75 molec. per cent that supplementary absorption bands in their spectra were observed apart from those absorption bands which must be assigned to known lead silicates. Those additional bands cannot be ascribed either to previously established lead silicates, to silica, or to contaminations, but exclusively to some other lead silicates which are not yet marked in the equilibrium diagram of this system.

In the interval of the compositions mentioned above, there is evidently a combination of lead silicates in which the degree of the bonding of the tetrahedra may be considerably varied. In conformity with this, the fundamental absorption bands of the silicates which correspond to the oscillations of the atoms in the $[SiO_4]$ tetrahedra may be substantially changed. Thus, the absorption band at 9 to 10 μ undergoes a shifting by about 2 μ if the PbO content is varied from zero to 75 per cent. Analogously, the spectra of glasses in which the lead oxide content is varied show a change in the corresponding bands that takes place in the same range of frequencies. It is evident that the bonds in the glass have much similarity with those of the corresponding silicates; the structure of the glass in some of its elements is built up on a certain resemblance with the structure of those silicates which are segregated in the crystallization of the given glass. To a well-known limit, namely approximately to 50 mol. per cent PbO, different modifications of silica also participate in the formation of the microstructure of the glass.

Fig. 6 shows the transmissivity of thin films of lead glasses with contents of 23 to 60 mol. per cent PbO. If the PbO content is raised up to 60 mol. per cent, the first fundamental absorption band is shifted from 9.5 to 11 or 11.2 μ, but if PbO is further increased, no more change occurs. Such a limit at the long-wave position for this band is characteristic in silicates whose crystal phase has an isle structure, i. e. when there is no uninterrupted mutual interlinkage of the tetrahedra[1]. The spectra of heavy lead glasses therefore indicate how the polymer-

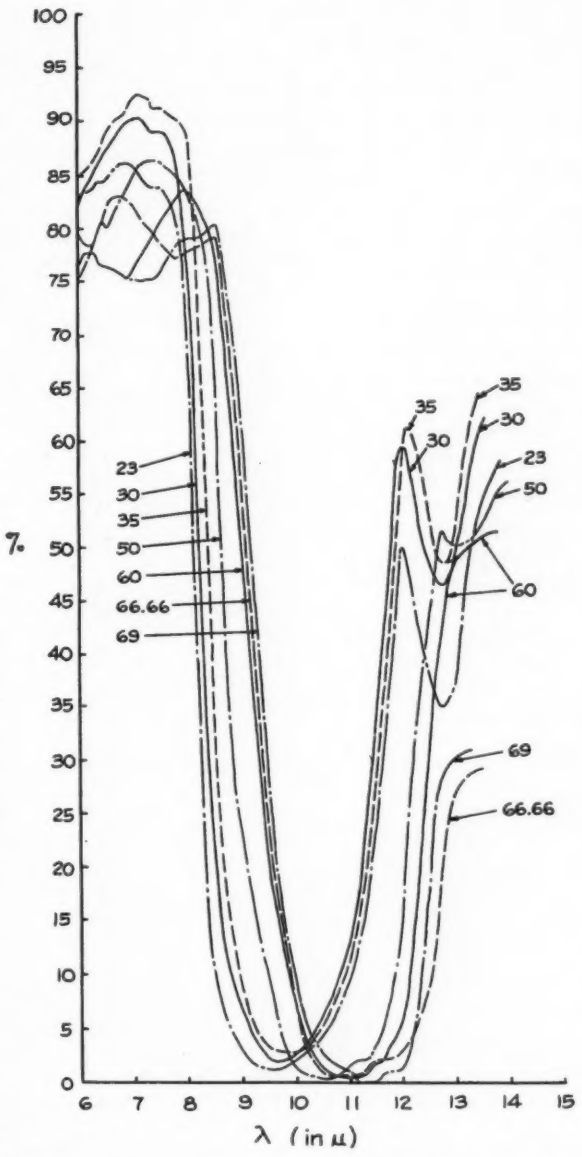


Fig. 6. Transmission spectra in the range from 6 to 13 μ, of thin films of binary lead silicate glasses with PbO contents between 23 and 69 mol. per cent.

ization of the tetrahedra is broken down in the glasses, the composition of which is close to the orthosilicate type.

With further increasing contents in metallic ions there is no more breaking down, and therefore no further changes in the bands occur. A decrease in the frequency for one and the same band demonstrates, in varying the composition of the glass, that the distance between the silicon ion and the oxygen in the tetrahedron is variable; it becomes a maximum in glasses of isle structure, a minimum in silica glass.

The second absorption band in the range from 12 to 13 μ is also somewhat changed by increasing contents in PbO, and is strongly weakened. If, however, the glass has the composition of the metasilicate it is still observed. We ascribe this band in lead glasses in the first place to the presence of crystallites of silica. Because it exists also in the composition of the glass corresponding to the metasilicate it is evident that the silicate in the glass discussed here must be partially dissociated. Gerlovin[7] who investigated the absorption of a film of a glass of just this composition did not observe such a band in the spectrum. When the first absorption band (at 9 to 10 μ) is shifted to its limit position corresponding to the isle structure, the second absorption band (in the range 12 to 13 μ) disappears.

What is the reason for the interpretation of this band as belonging to crystallites of silica?

Such an interpretation may be based experimentally on the fact that the band either exactly coincides with, or is very close to, the position characteristic for crystalline silica*. In the crystallization of lead glasses, which is accompanied by the segregation of silica, this band is only somewhat narrowed and comes exactly to the position which corresponds to a defined silica modification, or it is split up to a series of bands which are characteristic for different polymorphic forms of silica**.

Curve a′ in Fig. 7 demonstrates the transmission in the range between 12 and 13 μ of a film of a glass containing 30 mol. per cent PbO; curbe b′ demonstrates the transmission of a layer of the powder of the crystallized glass from the same melt. A comparison shows that the band became narrower only by the crystallization. From the spectrum one can identify also a segregation of tridymite. The minimum of the transmission at 12.70 μ is characteristic for tridymite. Curves a and b represent, for comparison, the analogous spectra of transmission for films and a crystallized glass with 35 mol. per cent PbO. The band is somewhat narrowed by the crystallization and splits up as quartz was segregated, which is indicated by the doublet with the minima at 12.55 and 12.85 μ, besides that of tridymite (minimum at 12.70 μ).

A comparison of the spectra of a glass film which represents the state of the melt, and of the crystallized glass, of one and the same composition, makes evident that in many lead glasses both are very similar to each other. Curves a and b in Fig. 8 show the transmission of the film of glass with 50 per cent PbO, and of a powder layer of the same glass in recrystallized form, respectively. The transmission minimum of the film lies at wave lengths which correspond to the strongest minimum on the transmission curve of the crystallized glass. Fig. 9 represents, for the same composition (but a different melt), the functional relation between the reflection coefficient of the ordinary (a), and the crystallized glass (b), with the wave lengths. Both specimens had an age of about 15 years. Immediately before the measurement their surface was ground and polished anew. The similarity of the spectra is even stronger in this case.

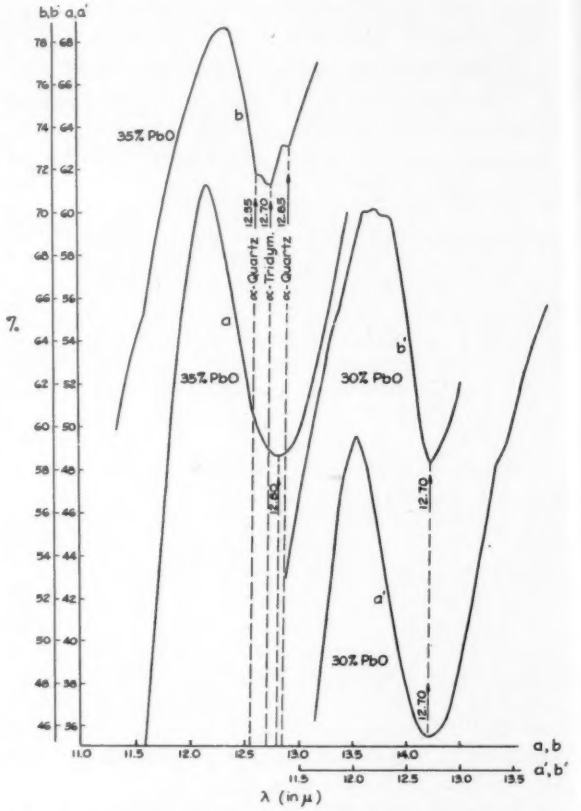


Fig. 7. Transmission spectra of lead glass films with 35 per cent and 30 per cent PbO (a, a′), and of thin layers of the powder of crystallized glasses of the same compositions (b, b′), in the range from 11 to 13.5 μ. [12.7 μ is characteristic for the trisilicate].

For a comparison of the behavior of other glasses with the same content of a metal oxide, Fig. 10 gives transmission curves for an unusually pure* sodium silicate glass with 50 per cent Na_2O (one and the same melt). Curves a, b, and v show the transmission of a film blown from the glass melt, a layer of powder from a monolithic lump which was produced by the cooling of the melt down to room temperature in the usual way, and crystallized glass, respectively. Fig. 10 shows that for a sodium silicate glass, although the metal oxide content is constant, the spectrum of the glass is considerably dif-

* In the case of glasses with a high PbO content, e. g. with 50 per cent PbO, the framework of the silica crystallites is the most deformed, because of the influence of the surrounding medium, and the band must be somewhat changed relative to the analogous band in the spectrum of glasses with a low PbO content.

** Meanwhile, this band is not always present in the spectra even of glasses which contain very much silica; in such cases, so far as it came to our knowledge, silica is not segregated in the devitrification of the glass.

* The sodium silicate glasses were fused in first-class silica glass; the samples of this silica glass of a thickness of 1 cm transmitted the light down to 1500 to 1550 Å. The silica was ground with balls of the same silica material. Soda was purified by the precision method of V. G. Voanno. The glasses were fused in platinum crucibles using a speed stirrer.

ferent from that of the crystallized silicate. In the place of one silicate band (minimum 10.2 μ on curve d), which corresponds to the first fundamental oscillation in the $[SiO_4]$ tetrahedron, now appear two bands which correspond to the same type of oscillation (curve a); hereby one of these is shifted to shorter waves (9.6 μ), the other to longer waves (10.8 μ). This indicates that in the glass melt the metasilicate of sodium is absent.

There are two kinds of atomic groupings in the melt: first, those with a degree of interlinkage of the $[SiO_4]$ tetrahedra higher than the lattice structure, not only higher than that of the sodium metasilicate but even that of the disilicate (the 9.6 μ band); and second, those with a degree of interlinkage lower than in the metasilicate. In other words, in the melt of the glass considered, there are on one hand areas with a high content in SiO_2, and on the other hand, areas with a high content in Na_2O; the structure of the melt is therefore heterogeneous.

Evidently, in lead glasses, different from other glasses, the lead ion plays a role of a certain centrally bound ion. Therefore there are present very early, already in the melt, formations that are close to the fundamental bonds which are characteristic for the silicates that segregate during the crystallization of the glass. The subsequent process of cooling of the glass brings about a subsequent increase in the degree of regularity in the system. Let

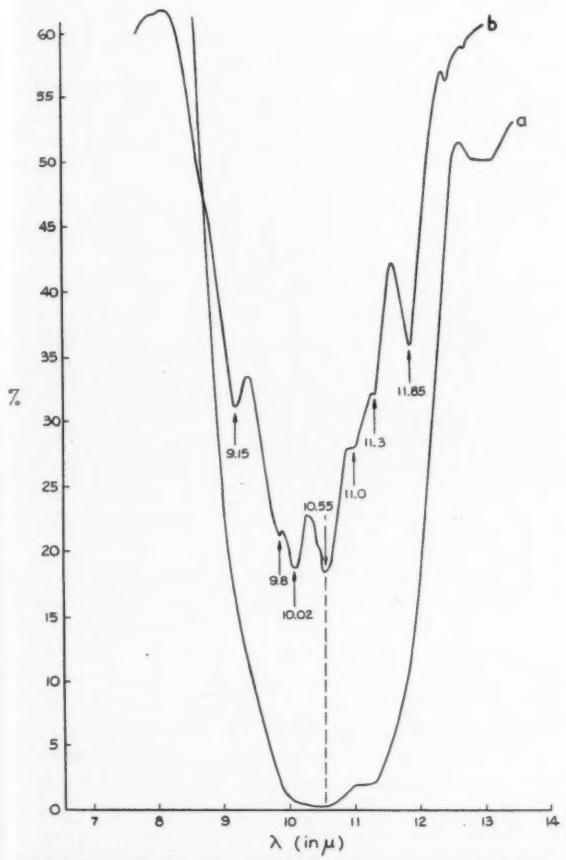


Fig. 8. Transmission spectra of glass films with 50 per cent PbO (a), and of a thin layer of powder of the crystallized glass of the same composition (b) in the range from 7 to 13 μ.

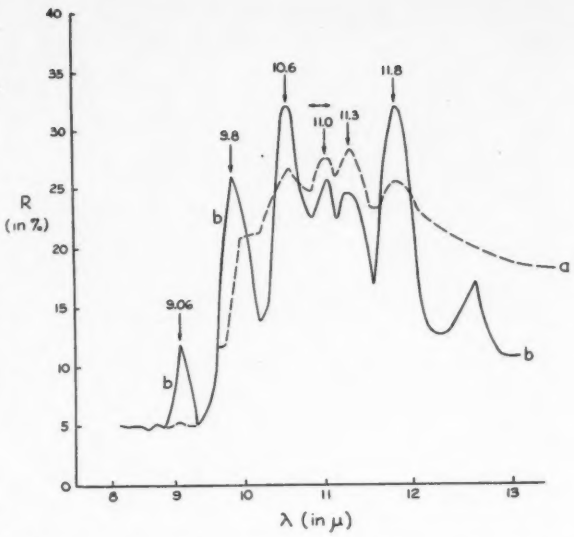


Fig. 9. Reflection spectra of the initial (a), and of the crystallized glass (b) with 50 per cent PbO.

us compare the curves a and b in Fig. 9. Numerous maxima and minima of the crystallized glass are already marked in the initial glass and conform in their positions. The difference from the reflection spectra shows, in principle, that the maxima of reflection in the glass are more diffuse and considerably lower in intensity. The maximum at 9.8 μ is also not observed in the glass spectrum, which perhaps corresponds to a silicate segregating as an accessory.

The similarity of the spectra demonstrates that the bonds which are characteristic for a defined chemical compound are inherent to the same glass, i. e., groups with regular positions of the atoms exist in the glass, or crystallites of the compounds occur which grow to visible crystals in the devitrifying glass under adequate thermal conditions. We assume that these crystallites have larger diameters than those indicated by the X-ray structure analysis. With diameters of 10 to 12 Å., the maxima of the absorption bands of the glass and of the silicates would scarcely coincide so accurately in their positions. These crystallites are bonded to one another by an interlayer which has a much less regular structure. The crystallites, together with the peripherical film of higher distortion, represent an area of local heterogeneity. The diameters of such areas must be considerably larger than the diameters of the crystallites themselves.

We imagine that the structure of binary lead silicate glasses is always highly complex and heterogeneous. We assume further that in its formation the silica participates in different modifications, together with a series of silicates among which some may be encountered that at the present time are not known to exist; all our present knowledge on the lead silicates is chiefly based on data of crystal-optical methods which have limited possibilities, and systematic investigations of methods of higher accuracy are not yet developed in this direction.

As a result of the superposition of the different structures which have elements of different degrees of regularity in common, one may in general obtain diffuse bands in the infrared spectra; the fine-structure of these

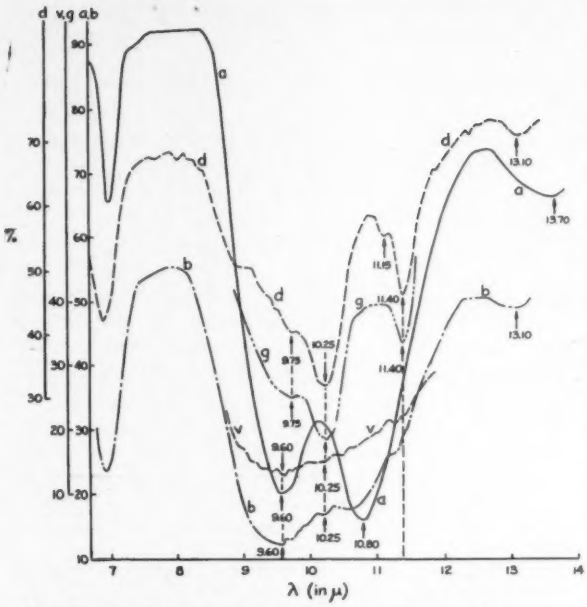


Fig. 10. Transmission spectra of metasilicate sodium glass in the range from 7 to 13.5 μ after different thermal treatments. Curve a—a thin film blown from the glass melt in fining state; b—a thin layer of powder of glass, cooled from the melt to room temperature; v—the same, annealed at 520° for 15 minutes; g—the same, annealed at 620° for 30 minutes, the glass devitrified; d—the same, of entirely crystallized glass, with coarse crystals of sodium metasilicate.

spectra cannot be determined even with all the possible accuracy of the measurements. This diffuseness of the bands, however, is also not a characteristic indication for a complete irregularity of the structure.

Sometimes, because of specific technological factors, or by the coincidence of some other opportune conditions, details in the spectra are detected which give some light on particularities of the structure. To learn of all the participating silicates will only be possible by a systematic control of the history of the glass in time of higher temperatures, when all the details of the spectra will be much clearer developed. Studies of this kind will doubtless add in the future much new information on the theory of the glass structure.

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POOLE WINS CHESTERMAN AWARD

Dr. James P. Poole of Brockway, Pennsylvania, has been named the winner of the 1957 Chesterman Award, which is sponsored by the American Bottlers of Carbonated Beverages, national association of the soft drink industry. The Award was made to Dr. Poole for his research and development work on a process of surface coating glass containers with silicones for protective purposes. Numerous papers by him on the silicone process were published in the trade press of the glass manufacturing and product packaging industries during 1954-1956. Dr. Poole is research director of the Brockway Glass Company.

The Citation and $1,000 cash Award will be presented to Dr. Poole at the Annual Banquet of the Society of Soft Drink Technologists, on April 1, at the Jung Hotel in New Orleans.

The Chesterman Award, coveted technical honor of the soft drink industry, is presented to the person who, in the opinion of the Awards Committee, has currently made outstanding scientific or technical contributions to the progress and advancement of the industry.

One of the greatest problems in recent years in glass container manufacture has been that of surface protection. Glass technologists have known for some time that the strength of glass is dependent primarily upon the condition of its surface with respect to abrasions and scuff marks. Effect of surface condition on the strength of glass containers is so important to maximum use that it tends to overshadow other factors affecting strength, such as chemical composition, type of test, and thermal history.

The work accomplished by Dr. Poole on his method of surface protection through the use of silicones has gained widespread acclaim in the glass manufacturing field and in the soft drink industry, a major user of the country's production of glass bottles. Older methods of surface protection of glass containers tended to become ineffective after the bottle washing process. In recent years the glass industry has attempted to overcome this by developing semi-permanent coatings. There are some in current use, including those produced by Dr. Poole's method.

The surface properties of a glass bottle having a properly applied silicone film provide a high degree of glass-to-glass lubricity, thus preventing cohesion and its detrimental effects on strength. The silicone film may be expected to last through several bottle washings, although in declining degree of protective effectiveness. Then it can be renewed.

L.O.F. TO BUILD CALIFORNIA GLASS FIBER PLANT

Contracts for the construction of a glass fiber manufacturing plant in Corona, California, costing in excess of $1,000,000 have been let and construction will start immediately, it was announced by G. P. MacNichol, Jr., chairman, and R. H. Barnard, president, L.O.F. Glass Fibers Company.

The new plant, for which a completion date of August 1, 1958 has been set, will be devoted to the manufacture, fabrication and warehousing of the complete line of L.O.F. Glass Fibers' insulation products, including its newly-introduced pipe insulation.

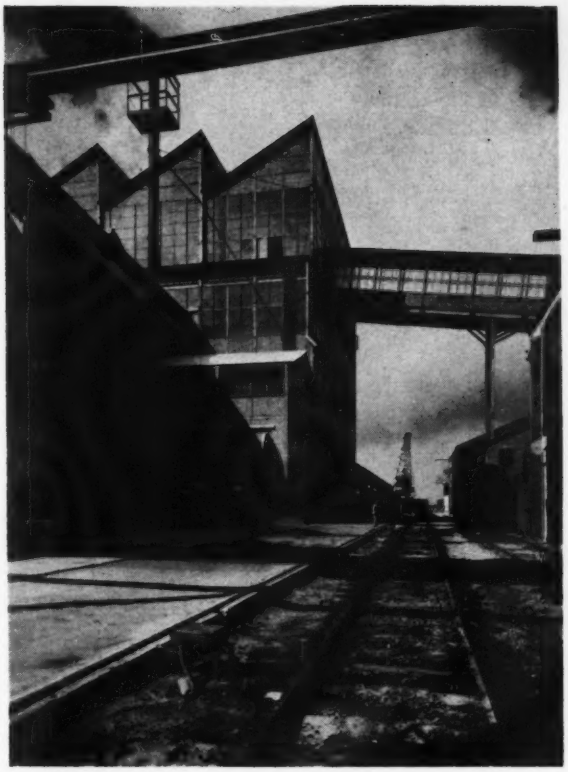
Being erected by the second largest manufacturer in the industry, it is the second West Coast facility devoted to the basic manufacture of glass fiber products. It is the latest step in West Coast activity by L.O.F. Glass Fibers which began operations in 1952 at a plant in Burbank, California, where specialized insulation products for the aircraft industry have been fabricated.

The company's entire Western operation, manufacturing and sales, is under the direction of John A. Morgan, vice president and general manager of the Pacific Coast Division.

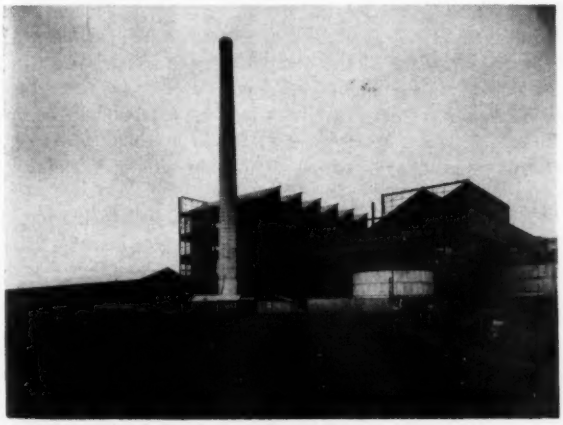
The new plant, expected to employ about 300 persons, will be built on land acquired in 1956 on the outskirts of Corona, a thriving industrial city of 15,000. It will have an area of 105,000 square feet.

Belgium Builds Largest Glass Furnace

THE WORLD'S LARGEST window glass tank furnace was recently put in operation at Zeebrugge, Belgium, a harbor situated on the North Sea Coast. It has a capacity of 2,400 tons of glass and an output of some 6,000 tons of drawn flat glass per month. The tank was built and is owned by the "Union des Verreries Mecaniques Belges" (Univerbel) and its capacity exceeds by 750 tons that of any previous large furnace ever built by any other glass producer.



Railroad siding is convenient to both plant and warehouse.



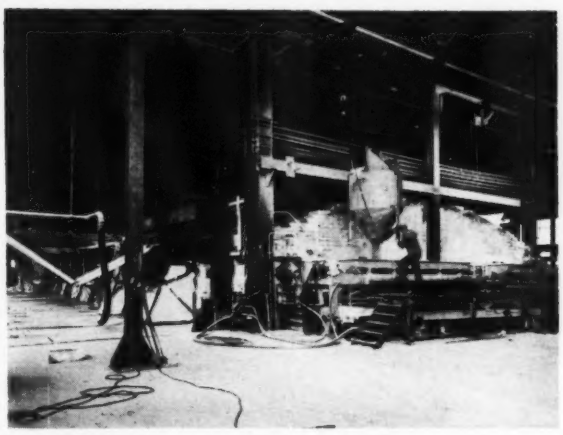
New Univerbel plant at Zeebrugge, Belgium, which houses world's largest glass tank furnace. Note the "complex" construction and the extensive use of glass which provides a maximum of natural lighting in the plant. Building at left is a warehouse for finished drawn glass.

The ten burners with which this new Belgian tank is equipped consume approximately 2,300 tons of fuel per month. The temperature of the injector flame is 3,024°F. The earlier furnace at the Zeebrugge glassworks was producer gas fired. Both tanks now use fuel oil.

Only a small number of workmen are required, since most of the operations are automatic: feeding the tank with raw materials, fuel, temperature and glass level control.

Over 7,000 tons of refractory materials were used for constructing the large tank (164 feet long) and the recuperating chambers. Since the furnace is about 33 feet above the ground level, more than 1,300 cubic yards of masonry were required to be placed for its foundation and under-structure. Foundations for the tank and its buildings rest on 700 40-foot long piles (driven into the ground) and 665 cubic yards of concrete.

The tank anchorage and the framework of the roof includes 3,500 tons of iron and steel. The plant's chimney is 230 feet high and it weighs over 70 tons. More than 22 miles of electric wires and cables were installed. About 54,000 square feet of masonry were required to



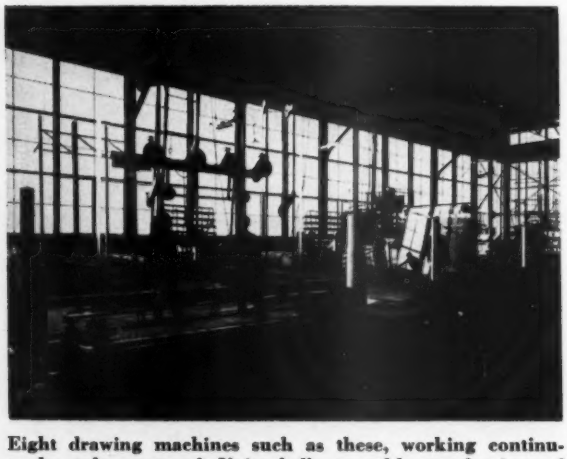
Large hoppers, traveling on overhead cranes, feed the raw materials into a mechanically operated trough at front of furnace. At left are fuel feed lines.

fill the framework of the buildings and 49,000 square feet of cement-asbestos plates covered the roof. In order that the new plant be well lighted with natural illumination, over 81,000 square feet of glass was used in the extremely large windows.

The packing shops recently built at Zeebrugge are approximately 525 feet long by 262 feet wide. There is a 360 foot loading dock having railway facilitie inside the buildings.

Largest window glass tank furnace showing workman peering through an inspection port. At left are the fuel oil feed pipes which supply the bank of burners in the lower part of the furnace.

After several years of wartime inactivity, the former Unverbel plant at Zeebrugge resumed operations in 1951. The eight glass drawing machines assured the plant of a monthly production of over 9,700,000 square feet of glass, reduced to single thickness (0.787 in.). With a period of uninterrupted production of 6 years, 2 months and 24 days the Zeebrugge tank furnace beat the world's glass tank duration record which was previously held by "Old Ben" at the American Window Glass Company at Arnold, Pa. "Old Ben's" record run was 5 years, 10 months and 24 days.



Eight drawing machines such as these, working continuously, take care of Univerbel's monthly production of over 8,000,000 square feet of drawn glass. As the ribbon lifts, cutters automatically cut to the required size.

Thickness of the sheet is determined by the speed of the drawing machines. After cutting, the pane is detached from the glass ribbon by means of suction cups, cut to sizes, selected and packed for shipment.

Other Univerbel plants are located in Lodelinsart, built in 1953, and in Gilly, built in 1955; both are in Belgium.

VIRGINIA GLASS PRODUCTS COMPLETES NEW PLANT

Virginia Glass Products Corporation of Martinsville, Virginia, has completed a new plant, built at a cost of over $1,000,000, for the manufacture of tempered glass under the trade name of "Tempar-Glas," William C. Beeler, president of the company, announced. The plant is said to be in full operation.

Employing the most modern manufacturing equipment, the plant is designed to produce the finest quality heat-strengthened, precision-tempered glass, Mr. Beeler said.

The large capacity of the plant will enable it to turn out tempered glass in any quantity. To back up this capacity, Virginia Glass Products has established reliable sources of supply in this country and abroad that will assure it a constant flow of glass for tempering.

The latest type electric furnaces have been installed in the plant. They will handle all sizes of glass—from the smallest to the largest size required by industry. "Tempar-Glas" will be available in a wide variety of colors in tempered plate, heavy sheet, patterned and spandrel glass.

Situated on a 62-acre tract of land, the new fireproof plant has 110,000 square feet of floor space.

Complete loading and unloading facilities are located inside the plant. The site is adjacent to the Norfolk and Western Railway and a state highway.

Virginia Glass Products will have its own box factory for crating "Tempar-Glas." The box factory is now under construction and should be completed soon after January 1.

The management of Virginia Glass Products, headed by Mr. Beeler, has had long experience in the glass industry. Louis D. Toussart, a pioneer in the field of tempered glass, has been appointed production manager. The sales department will be headed by Brooks Leavitt, sales manager.

Inventions and Inventors

Annealing and Tempering

Sealing Cathode Tubes. Patent No. 2,793,472. Filed March 30, 1955. Issued May 28, 1957. One sheet of drawings; none reproduced. Assigned to Owens-Illinois Glass Company by William G. N. Heer and Bernard L. Stelerman.

This invention relates to the sealing and assembling of cathode tubes and in particular, to the sealing of tubes adapted for the transmission of images in color.

The primary object of this invention is to provide a heat radiation shield or screen of a type capable of repelling excessive heat from contact with the color mechanism.

A collapsible bag is extended through the funnel portion of a cathode tube. Water or other coolant is admitted to the bag and the weight of the coolant causes it to expand and provide a protective covering over the color mechanism.

When the bag has been expanded, the two glass parts have their adjoining edge surfaces brought into contact and heat, such as supplied by a combustion burner, is applied to the edges to soften the glass and bring it to a sealing condition. With the completion of the sealing operation, the coolant to the collapsible bag is discontinued and the bag may then collapse and be withdrawn through the restricted neck portion of the funnel section of the tube.

Another form of the invention provides for the use of a foil heat radiation screen which may be formed from two or more sheets of aluminum foil maintained separate from each other by an interposed sheet of crimped or dimpled form. These foil sheets are so thin that they will drape themselves in such a manner that they may easily be removed through the neck portion of the funnel of the tube. In this form it is not necessary to have a coolant because the foils are generally of a highly reflective nature and if made of aluminum, are capable of withstanding temperatures in excess of 1000° F. Because of the reflective nature, the heat is reflected away from the color mechanism of the tube during the sealing operation.

There were 4 claims and the following reference cited in this patent: 2,691,850, Eber et al., Oct. 19, 1954.

Feeding and Forming

Coated Lamp. Patent No. 2,781,654. Filed October 1, 1953. Issued Feb. 19, 1957. One sheet of drawings; none reproduced. Assigned to General Electric Company by Marvin Pipkin.

Good results may be attained when the interior surface of a bulb is coated with a lacquer comprising essentially about 300 to 400 parts by weight polymerized vinyl acetate (Vinylite) resin solution, about 5 to 100 parts by weight acetone, about 20 to 70 parts by weight alcohol, about 93 to 146 parts by weight ethyl silicate.

In the curing operation the interiorly coated bulb is heated at about 60-70° C. for a period of about 3-8 minutes, preferably 5 minutes. A proper cure has been achieved when the frosted interior coating has assumed a completely clear or transparent appearance. The curing step also serves to remove excess solvent in the lacquer.

If a diffusing coating is desired, the interior lacquer may be left in the frosted condition by elimination of the curing step.

It is believed that the desired frosted appearance is achieved on air-drying of the lacquer of this type by the evaporation of the solvents (acetone and alcohol) leaving Vinylite, nitrocellulose and ethyl silicate as a three-component, immiscible system in which the said immiscibility of the components rather than any particular component produces the frosted appearance. Upon curing the air-dried film as previously mentioned, the ethyl silicate, which is the most volatile component of the immiscible system, evaporates leaving what appears to be a colorless solution of Vinylite and nitrocellulose which are apparently miscible, rendering the final heat-cured lacquer film clear and colorless.

There were 9 claims and the following references cited in this patent: 2,046,388, Lurlander, July 7, 1936; and 2,571,607, Pipkin, Oct. 16, 1951.

Furnaces

Coated Refractory For Contacting Molten Glass. Patent No. 2,777,254. Filed October 22, 1952. Issued January 15, 1957. One sheet of drawings; none reproduced. Assigned to Owens-Corning Fiberglas Corporation by August C. Siefert and Robert J. Cunningham.

This invention relates to improved refractory materials for feeders, tanks and the like, and particularly to coated refractory materials suitable for contacting molten glass.

Parts made of platinum and platinum alloys have been used in the past to replace refractory members at points of most severe attack on the surfaces of the glass handling apparatus. This procedure has been found to be unsatisfactory for general use due to the physical properties of platinum, including its inherent softness, which make it necessary to make such installations with relatively heavy and very expensive wall sections.

The objects of the invention are attained by securing a thin foil of a metal, including those metals and alloys of metals which are suitable for contacting molten glass and including platinum and its alloys, upon the surface of a conventional refractory material. This foil covered refractory material is then used to construct glass handling apparatus such as glass melting tanks, stirring apparatus, feeders, and the like.

In producing refractory blocks, a refractory block of zirconium silicate is coated with a thin layer of alumina which is dusted upon the refractory surface. Next the alumina is covered with a foil of platinum and the composite structure is weighted by placing blocks of refractory or other heat resistant material over the platinum foil. The structure is fired at a temperature of 3030° F. for a sufficient length of time to cause a reaction between the alumina and the refractory block of zirconium sili-

cate. The reaction product, upon cooling, forms a strong glass which bonds the platinum foil to the zirconium silicate refractory.

There were 7 claims and 17 references cited in this patent.

Glass Compositions

Optical Glass. Patent No. 2,776,217. Filed August 21, 1953. Issued January 1, 1957. No drawings. Assigned to Deutsche Spiegelglas Aktiengesellschaft by Otto Gott.

It is desirable to find a glass composition which provides a neutral colored or slightly brown optical glass, e. g. for spectacle lenses, and also a light transmission of 70 to 85 per cent and an adequate absorption in the heat radiation range.

The following is an example of the composition of a glass in accordance with the invention, showing the particular constituents in precise proportions by weight:

SiO_2	72.26 per cent
Na_2	12.75
CaO	11.00
K_2O	3.75
FeO	0.11
Fe_2O_3	0.01
TiO_2	0.12
Se	0.002

The same optical qualities are obtained if the titanium oxide is replaced by tungstic oxide.

In such silicate glasses the combination of oxides produces a color complex in which the absorption of infrared radiation by the ferrous iron remains effective from neutral grey to slightly brown tints and at the same time there is only a very minor amount of absorption in the visible range.

There were 2 claims and the following reference cited in this patent: 1,830,902, Hood, Nov. 10, 1931.

Glass Wool and Fiber

Process for Making Fibrous Glass Sheet. Patent No. 2,765,587. Filed February 2, 1953. Issued Oct. 9, 1956. Two sheets of drawings; none reproduced. Assigned to Economatic Products Company, by Roy P. Skerritt.

This invention relates to compressed porous plates made from fibrous glass and, in particular, to processes for making such plates.

The fibrous glass bats or blankets are compressed vertically while stacked in horizontal layers, then clamped together in a compressed assembly, and the assembly placed on edge with the layers vertical while subjected to a high heat which volatilizes any binder which may be present on glass fibers and causes the fibers to become tacky and coalesce, the heat being applied relatively slowly in comparison with prior glass fiber heating processes.

There were 3 claims and 11 references cited in this patent.

Sheet and Plate Glass

Timer Controls for Automatic Glass Cutting Machine. Patent No. 2,763,928. Filed March 8, 1952. Issued Sept. 25, 1956. Four pages of drawings; none reproduced. Assigned to Pittsburgh Plate Glass Company, by Harry A. Smith, Jr.

This invention relates to the control of translation speed of cutting machines that have a template follower for propelling a cutting head along a predetermined path across a work piece.

With glass cutting machines, it has been found satisfactory to move a scoring tool along a straight line on the glass at a faster rate than when moving around sharp curves. Such machines have been equipped with limit switches placed at selected locations along the template for effecting a change in speed as the template follower approached each right angle or other sharp curve of the template. The removal and relocating of these limit switches with each change of template has been a time-consuming job and one requiring considerable skill.

It is an object of this invention to provide improved speed control apparatus for cutting machines, and more particularly to provide timers which have no connection with the template shape and template follower speed that they may operate the follower speed control as the follower approaches each of the sharp curves of the template.

Other features of the invention relate to the starting of timers simultaneously with the starting of the template follower; to a construction in which a single timer restores the speed control to its original condition after each operation by a plurality of other timers; and to the ultimate control of the starting by the arrival of a work piece in position to be cut, when used on automatic machines.

There were 18 claims and the following references cited in this patent: 1,474,991, Yerger, Nov. 20, 1923; 2,118,170, Crowley et al., May 24, 1938; 2,211,985, Peters, Aug. 20, 1940; 2,364,644, Mott et al., Dec. 12, 1944; 2,573,653, Schrock, Oct. 30, 1951; 2,576,291, Fletcher, Nov. 27, 1951; 2,612,689, Kirkman et al., Oct. 7, 1952; and 2,618,857, Foralske, Nov. 25, 1952.

Improved Glass Cutting Method. Patent No. 2,764,848. Filed October 17, 1952. Issued October 2, 1956. One sheet of drawings; none reproduced. Assigned to Pittsburgh Plate Glass Company, by Florian V. Atkeson.

This invention relates to a novel glass cut running method utilizing various solutions that assist in the running of the cut and is particularly concerned with those types of solutions which may be used in conjunction with glass cutting and running implements to increase the efficiency thereof.

A few examples of certain typical substances that can be utilized as surface active agents include such water soluble materials as alkyl aryl sulfonates, isopropyl napthalene sodium sulfonate, fatty acid esters, low molecular weight ethylene oxide condensates, and amine salts of long chain acids.

The solution may be applied to the score produced in the glass due to a glass cutting implement either by a brush or a cotton swab inundated in the solution. The improved results are obtained by utilizing the wetting agent despite the fact that cutting oil is present on the cutter and a portion of this oil is removed from the cutter to the scored glass surface during the cutting operation. In cases where a solution of the type described was used,

the cut obtained showed smoother edges, no flares, and no shatter shadows.

It has been found that by applying dilute solutions of water containing water soluble wetting agents considerably less force is required.

There were 4 claims and the following references cited in this patent: 989,603, Horning, Apr. 18, 1911; and 2,470,444, Philippe, May 17, 1949.

Tube and Cane Machines

Fabricating Glass Rod. Patent No. 2,786,793. Filed July 6, 1954. Issued March 26, 1957. One sheet of drawings; none reproduced. No assignee. By Samuel Merle Shobert.

The present invention relates to a method of fabricating glass rod and more particularly to a method for producing glass reinforced plastic rod which is suitable for use in making fishing rods.

The method comprises arranging a plurality of glass threads substantially parallel into a longitudinally extending bundle and wetting the bundle throughout with a liquid resin. The wetted bundle is then gathered into a self-supporting cross-sectional shape after which it is hung for curing. The resin securely bonds the bundle together requiring no externally applied holding means for retaining the cross-sectional bundle shape.

There were 8 claims and the following references cited in this patent: 2,311,704, Simison, Feb. 23, 1943; 2,558,355, Knewstubb et al., July 3, 1951; 2,602,766, Francis, July 8, 1952; 2,625,498, Koch, Jan. 13, 1953; 2,653,887, Slayter, Sept. 29, 1953; 2,684,318, Meek, July 20, 1954; and 2,741,320, Jacobs et al., June 19, 1956.

Miscellaneous Processes

Making Twine and Apparatus Therefor. Fig. 1. Patent No. 2,732,883. Filed May 10, 1952. Issued January 31, 1956. One sheet of drawings. Assigned to Owens-Corning Fiberglas Corp. by A. R. Morrison and H. E. Fargo.

This invention relates to twine and, more specifically, twine of glass fibers such as baler or other similar twines.

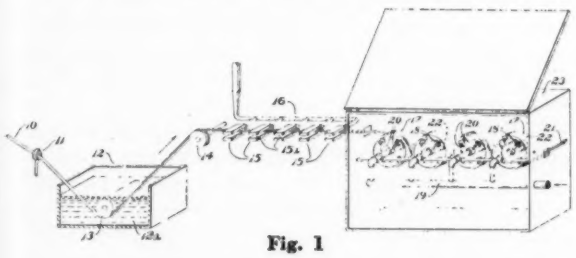


Fig. 1

A suitable coating mixture is prepared as follows: 750 parts of an aqueous emulsion (40 per cent solids) of the residue remaining after separation of refined rosin from the resinous extract of pinewood is mixed with 750 parts of a 40-60 butadiene styrene latex (48 per cent solids) and 180 grams of a dispersion of zinc stearate (25 per cent solids), and to this mixture is added 1320 parts of water. The resulting bath has 23.5 per cent total solids, 10 per cent of which is the residue remaining after the separation of refined rosin from the resinous extract of wood, 12 per cent of which is synthetic rubber, and 1.5 per cent of which is zinc stearate.

Radiant burners 15-15 (see Fig. 1) flash off the greater proportion of the water of the coating solution or emulsion. The temperature within these radiant burners is from about 1200° to 1500°F. and preferably from 1250° to 1450°F. Rolls 17-17 then heat the ribbon, upon which has been deposited the suitable coating ingredients, to temperatures of from 400° to 600°F. and preferably from about 450° to 550°F. in order to completely dry and fuse these ingredients into a suitable coating upon the ribbon 21, which is twisted and formed into a suitable package of twine, as desired.

A twine prepared by dipping the strands of fibrous glass in a dipping bath of Fig. 1 and cured with the two step heating apparatus shown in the drawing provides a product having the tensile strength of 450 pounds or greater as well as very good knot strength, surface lubricity and non-abrading properties. The zinc stearate bleeds out to the surface of the twine where it lubricates the surface of the twine very effectively.

There were 15 claims and the following references were cited in this patent: 1,994,057, Wallach, Mar. 12, 1935; 2,345,541, Scholze, Mar. 28, 1944; 2,389,459, Remark et al., Nov. 20, 1945; 2,496,911, Green, Feb. 7, 1950; 2,498,338, Martin, Feb. 21, 1950; 2,550,465, Gorski, Apr. 24, 1951; 2,625,498, Koch, Jan. 13, 1953; and 2,633,428, Klug, Mar. 31, 1953.

Acid Stamping Glassware. Fig. 2. Patent No. 2,738,607. Filed April 29, 1954. Issued March 20, 1956. Three pages of drawings. Assigned to Owens-Illinois Glass Company by John H. Beddoes and Victor J. Zitkus.

The invention relates to apparatus for transferring articles from one position or carrier to another and for stamping or applying surface markings to the articles at an intermediate position during the transfer, such markings comprising lettering, decorations, trade-marks and other insignia.

The stamping mechanism (see Fig. 2), includes a stamping head 75 mounted on a horizontal shaft 76 for rotation.

The stamping dies are carried on heads 85 attached to the member 75 and extending radially. Each stamping unit includes a die with a design. The die may consist of hard rubber or rubber composition attached to a block consisting of rubber or the like, said block being mounted in a thimble 88 which is removably attached to the head 85 by a bayonet slot and pin connection. The die carrying member or head 75 is removably attached to a tubular member fixed to the shaft 76 and formed with a tubular extension which provides a bearing for the member 75. This construction permits the head 75 to be dismounted when desired.

The stamping or marking material, which for stamping glassware comprises hydrofluoric acid, is supplied from a well 101 mounted on an arm 102. The etching acid is transferred to the stamping dies 86 by an acid pick-up wheel or disk 103 journalled for the free rotation about its axis. The disk is intermittently rotated by frictional engagement with the dies 86, thereby transferring the acid and applying it to the dies. The gears rotate the dies at the same peripheral speed as that at

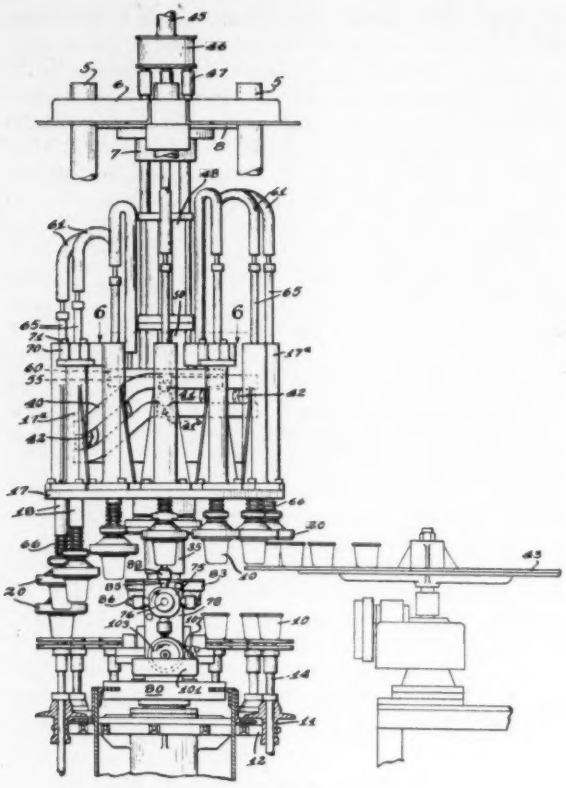


Fig. 2

which the suction heads 20 and tumblers 10 are moving during the stamping operation, thus avoiding any smudging of the etching acid or other marking material.

There were 15 claims and the following references were cited in this patent: 2,543,186, Miller, Feb. 27, 1951; and 2,647,337, Martin, Aug. 4, 1953.

Shipping Container for Glass. Fig. 3. Patent No. 2,741,362. Filed April 24, 1953. Issued April 10, 1956. Two sheets of drawings. Assigned to General Motors Corporation by Samuel E. Cortright.

The packing strip is constituted (Fig. 3) of three separately formed layers, including an inwardly disposed corrugated strip 5, a corrugated intermediate strip 6 and an outer flat backing strip 7 which is inextensible longitudinally but capable of being bent at right angles to its plane.

In the formation of the packing layers the innermost strip 5 has cut therein a series of longitudinally spaced slots 8 intermediate the side edges thereof, and is also provided with a series of transversely extending and longitudinally spaced score lines to facilitate the working of the strip into the corrugated or wavy outline illustrated in the drawings. The two strips 5 and 6 when brought together with the projections nested one within the other and the flat base portions in seated relation are then joined in the regions of their bases to the flat backing strip 7 by gluing, riveting or stapling so that the inextensible backing strip ties the pair of cooperating corrugated strips against collapse or distention.

For packing individual sheets singly in one carton the strip may be cut to a length in excess of the peripheral dimension of the glass so that the strip can be applied to the glass with its opposite ends overlapping and these ends may be stapled or glued together so that the glass, with its edges pocketed within the slots, is completely ringed by the packing.

For shipping a group of articles in a single container a series of the strips may be placed side by side and inserted in succession in the container.

There were 13 claims and the following references were cited in this patent: 1,802,522, Moll, Apr. 28, 1931; 2,261,280, Pennebaker et al., Nov. 4, 1941; and 2,431,535, Bergstrom, Nov. 25, 1947.

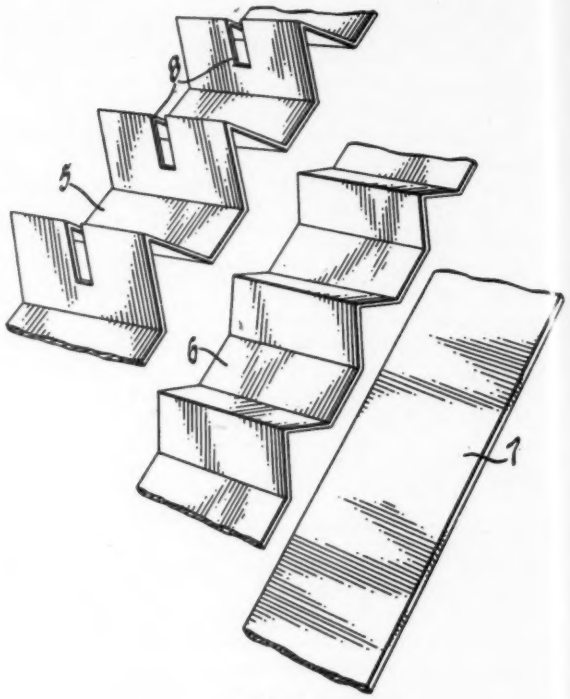


Fig. 3

Illuminating Glassware. Patent No. 2,749,794. Filed April 24, 1953. Issued June 12, 1956. One page drawings; none reproduced. Assigned to Corning Glass Works by Thomas G. O'Leary.

This invention relates to illuminating glassware comprising a sheet or hollow glass body having translucent portions forming indicia such as louvers and decorative designs and adapted to be illuminated from the side opposite the observer.

It has been discovered that glare can be effectively diminished without decreasing the transmission of light or the visibility through the transparent portions by removing the translucent portions to a desired depth to form depressions in the surface of the glass body in register with the translucent portions and introducing into the resulting depressions a light-absorbing material.

While strongly light-absorbing and adherent materials such as finely divided carbon can be utilized without a binder, it is generally preferable to disperse the colorant in a solid carrier, for example, a thermosetting resin. To

(*Continued on page* 116)

Fracture of Glass Under Various Liquids and Gases

• IT IS WELL ESTABLISHED that contact with water decreases the strength of glass. A glass-blower finds it easier to break a piece of glass, if, having made a scratch with a diamond, he then moistens it. This effect of wetting may be explained by the theory of Griffith (1920) that the rupture of a solid depends on the surface energy. A liquid which reduces the surface of energy of glass will also reduce its strength.

Milligan (1929) carried out a series of experiments on the effect of liquid water, water vapor, alcohol vapor, and paraffin oil on the strength of window glass. A set of blocks was marked with a glass cutter and the breaking load of the blocks was found when they were treated with various liquids or exposed to different atmospheres. The presence of dry paraffin oil increased the strength of glass as compared with the strength in air, whereas liquid water, water vapor, and alcohol vapor all reduced the strength by about 20 per cent.

Further work was carried out by Schurkov (1932) on the effect of moisture on the strength of glass fibers or fused quartz. Benedicks and co-workers (1949) found that most liquids reduced the breaking load of glass but that some, e.g. toluene, Photogen, and tar lubricating oil, had a considerable strengthening effect. Ramsauer (1951) studied the effect of liquids on the hardness of quartz and glass. Baker & Preston (1946) worked with glass under high vacuum. They found that fatigue was mainly due to the action of water vapor acting in flaws. Gurney (1952) compared the delayed fracture in various atmospheres and verified that glass has a far higher strength in vacuo than in air. The experiments in air from which water vapor and carbon dioxide were excluded in turn indicated that both these substances have an effect on delayed fracture.

Although a considerable amount of work has already been done on the fracture of glass in contact with various liquids and gases, the results depended for their accuracy on the breaking of a large number of specimens. It appeared that measurements on cone fractures as described recently by Roesler (1956) might afford a more convenient and accurate method for investigating the effect of liquids and gases on the strength of glass.

Roesler deduced the following formula for the fracture energy T in terms of the angle of the cone a, the radius of the cone crack R, the shear modulus G, the indenter force P, and a constant ω.

$$T = \frac{\omega P^2 \sin a}{4\pi G R^3}$$

ω is a number depending on a and ν (Poisson's ratio). It has to be determined by a long numerical calculation and has been found hitherto only for a = 68° 12′ and $\nu = 0.25$; its value then is, approximately, $7{\cdot}45 \times 10^{-3}$.

Using glass from the same batch of commercial plate glass as was used by Roesler, C. J. Culf reports in the April 1957 issue of the *Journal of the Society of Glass Technology* the results of a study along these lines.

The glass was cut into blocks 2x2x1½ in. Each block was cracked in a hydraulic ram under an indenter which consisted of a solid base with a short flat-ended cylindrical steel tip as a punch. The cone fracture first forms around the punch as a ring crack. As the pressure increases the crack spreads downwards and outwards and takes up the shape of a cone. At high pressures the block of glass is liable to shatter and as a safety precaution a Perspex cage was always placed over the specimen.

In each experiment, the diameter of the cone fracture was measured with a travelling microscope. In order to see the crack, two opposite side faces of the block were ground smooth and cover slides were mounted with a colourless form of Canada Balsam, thus making the surface transparent. Three of the optical glasses had a very high refractive indices and it was necessary to mount the slide with a liquid of matching refractive index. Bromoform, bromobenzene, and a mixture of methylene iodide and bromobenzene were used for these glasses.

The diameter of the crack was measured after the specimen had been loaded for 15 minutes. This period was chosen for convenience since by this time the crack was growing quite slowly and could be measured accurately. The cone was grown stepwise, by increasing the pressure after each reading, and thus several values for P^2/R^3 were obtained for the same specimen. The pressure was increased each time by at least 10 per cent so that the diameter of the crack formed was not affected by the previous loading. Usually two specimens were used for each gas or liquid, and the value for the diameter of a well-formed cone for two different specimens cracked under the same substance did not differ by more than 3 per cent.

In Table 1 are given the loads required to form a cone fracture of diameter 2·3 cm. in plate glass cracked in contact with various liquids and gases. Values for the fracture energies are also given.

Growth curves were obtained for cone fractures formed under nitrogen, ammonia, carbon dioxide, sulphur dioxide, air, silicone oil, and water by measuring the diameter of the crack at various intervals of time, the pressure being kept constant.

A long-term experiment was carried out on the effect of water on glass and it was found that after about 3 days the diameter of the crack reached a stable value. When carbon dioxide was used, the limiting value was reached after 4 hours, and when silicone oil was used, the limiting value was attained after 1 min. Silicone oil seems to inhibit the growth of the crack, and Wessel (1955) suggests that this may be due to the reaction of the silicone with the absorbed film of water on the glass surface.

The growth curves indicate a correlation between fatigue and the lowering of the fracture energy of glass by certain liquids and gases. Baker & Preston (1946) observed that fatigue of glass is caused by the action of water vapor and adsorbed gases acting in flaws. A block of glass under a load may not fracture immediately, but if water is present, will break when the fracture energy is sufficiently low. The fracture energy of glass

in contact with water vapor or liquid water does not reach a minimum for several days.

The effect of water on the tensile strength of glass is considerable and tends to mask the effect of other substances. There are certain liquids and inert gases, e.g. petroleum ether, liquid paraffin, nitrogen, which apparently increase the surface energy of glass. It is more probable that, in fact, their main action is to keep the moisture of the air away from the fracture.

It should be stressed, however, that water is not the only reactive substance. The ammonia was carefully dried and yet the crack which formed under ammonia was much larger than that formed under nitrogen, sulphur dioxide, or carbon dioxide. Ammonia is far more readily adsorbed by glass than the other gases and may possibly change the chemical composition of the surface, thereby reducing the surface energy needed to form a cone crack. The recent work of Petch (1956) has also shown that the lowering of fracture energy may be due to surface adsorption.

As all these surface effects are closely connected, it is probable that the heat of adsorption of a gas in contact with glass as well as the amount adsorbed is an indication of the lowering of the fracture energy. It should also be possible to correlate the heat of wetting of the liquids with the fracture energy of plate glass in contact with these liquids.

Table I

The Fracture Energy of Plate Glass Cracked Under Various Liquids and Gases

Substance	Load in 10^6 dyn. required to produce crack of diameter 2·3 cm. in 15 min.	Fracture energy in dyn. cm. $^{-1}$
Distilled water	1660	2900
Sodium silicate	1770	3300
10% NaOH Solution	1810	3500
"Teepol" (a liquid detergent)	1810	3500
Acetone	1860	3700
Mercury	1860	3700
Air (varies with humidity)	1860-2010	3700-4300
50% KOH solution	1900	3800
n-butyl alcohol	1900	3800
n-propyl alcohol	1940	4000
Ethyl alcohol	1940	4000
Phosphoric acid	2000	4200
Ammonia (gas)	2000	4200
Chloroform	2220	5200
Glycerol	2500	6600
Cyclohexane	2530	6800
Liquid paraffin	2560	6900
Petroleum ether (b.p. 100-120)	2560	6900
Silicone oil (MS200)	2590	7100
Sulfur dioxide (gas)	2650	7500
Nitrogen (gas)	2690	7600
Carbon dioxide (gas)	2720	7800

KNOX APPOINTS H. E. STEELE

Knox Glass Incorporated of Knox, Pa., has appointed Howard E. Steele as manager of manufacturing in its seven plants. He assumed his new duties at the Knox, Pa., headquarters of the firm on January 1, according to Dr. Arthur W. Wishart, Knox president.

H. E. Steele

In his new position, he will supervise operations for the company's plants at Knox, Marienville and Parker, all in Pennsylvania, two plants at Jackson, Miss., the Gas City, Indiana, plant, and the recently expanded plant at Palestine, Texas. He will also be responsible for the new plant which is being built by Knox at Danielson, Connecticut.

Since 1951, Mr. Steele has been manager of the Westinghouse Electric Corporation's glass plant at Fairmont, W. Va. He began his career in the glass industry with the Corning Glass Works at Wellsboro, Pa., in 1928 as a machine operator. He subsequently became melting foreman, and in 1942 was transferred to Corning's plant at Parkersburg, W. Va., as assistant manager. From 1945 until 1951, when he joined Westinghouse, he was assistant to the manager of the Charleroi, Pa., Corning plant.

Mr. Steele is married to the former Ila Watkins of Wellsboro and is the father of a daughter and two sons. He is a member of the American Ceramic Society.

ENGELHARD INDUSTRIES, INC. FORMED

Formation of a new corporation with annual sales in excess of $200 million, the world's largest fabricator of precious metals and one of the 200 largest industrial companies in the United States, was recently announced by Charles W. Engelhard, New Jersey industrialist.

Named Engelhard Industries, Inc., it was formed by a consolidation of nine American companies in the precious metals and precision-manufacturing fields, some of them over 50 years old. Three other domestic companies and twelve foreign corporations also are controlled by the same interests, it was disclosed.

Largest of the firms consolidated into Engelhard Industries, Inc., is Baker & Company, Inc., which grossed some $53-million last year. Its main business has been the refining and fabrication of platinum. Another is the 50-year-old Hanovia Chemical & Manufacturing Company, producers of liquid precious metals for the glass and ceramic industries.

The other consolidated companies are: The American Platinum Works, refiners and workers of silver; Amersil Company, manufacturers of fused quartz; East Newark Industrial Center, Inc., managers of some 1-million sq. ft. of industrial property; Irvington Smelting & Refining Works; D. E. Makepeace Company, producers of atomic-reactor components and precious-metal materials; National Electric Instrument Company, manufacturers of industrial and medical instruments; and The H. A. Wilson Company, producers of thermostatic materials, electrical contacts, laminated metals, and special alloys.

Current Statistical Position of Glass

Employment and payrolls: Employment in the glass industry during November, 1957 was as follows: *Flat Glass:* A preliminary figure of 29,400 for November, 1957 indicates an increase of 1.4 per cent from the adjusted 29,000 reported for October, 1957. *Glass and Glassware, Pressed and Blown:* A decrease of .97 per cent is shown by the preliminary figure of 81,700 for November, 1957, when compared with the adjusted figure of 82,500 for October, 1957. *Glass Products Made of Purchased Glass:* The preliminary figure of 13,500 for November, 1957 indicates a decrease of 4.3 per cent from the previous month's adjusted figure of 14,100.

Payrolls in the glass industry during November, 1957 were as follows: *Flat Glass:* An increase of 8 per cent is shown in the preliminary $15,837,149.66 when compared with October, 1957's adjusted $14,671,711.32. *Glass and Glassware, Pressed and Blown:* An increase of 1.3 per cent is shown in the preliminary $30,345,392.89 reported for November, 1957 when compared with the previous month's adjusted $29,944,747.15. *Glass Products Made of Purchased Glass:* A preliminary figure of $4,214,005.82 was reported for November, 1957. This is an increase of 10.7 per cent when compared with the adjusted figure of $3,803,534.13 for the previous month.

GLASS CONTAINER SHIPMENTS

(All Figures in Gross)

Narrow Neck Containers	Dec., 1957
Food	779,000
Medicinal and Health Supplies	1,370,000
Chemical, Household and Industrial	605,000
Toiletries and Cosmetics	560,000
Beverage, Returnable	825,000
Beverage, Non-Returnable	78,000
Beer, Returnable	81,000
Beer, Non-Returnable	465,000
Liquor	633,000
Wine	353,000
Sub-total (Narrow)	5,749,000
Wide Mouth Containers	
Food	*2,617,000
Medicinal and Health Supplies	376,000
Chemical, Household and Industrial	124,000
Toiletries and Cosmetics	192,000
Packers' Tumblers	52,000
Dairy Products	154,000
Sub-total (Wide)	*3,515,000
Total Domestic	9,264,000
Export Shipments	230,000
TOTAL SHIPMENTS	*9,494,000

* This figure includes Fruit Jars and Jelly Glasses.

GLASS CONTAINER PRODUCTION AND INVENTORY

(All Figures in Gross)

		Production Dec., 1957	Stocks Dec., 1957
Food, Medicinal and Health Supplies; Chemical, Household and Industrial; Toiletries and Cosmetics	Narrow Neck	3,992,000	6,403,000
	Wide Mouth	*3,697,000	5,421,000
Beverage, Returnable		844,000	1,783,000
Beverage, Non-Returnable		73,000	215,000
Beer, Returnable		121,000	300,000
Beer, Non-Returnable		517,000	745,000
Liquor		803,000	1,454,000
Wine		457,000	663,000
Packers' Tumblers		38,000	88,000
Dairy Products		166,000	280,000
TOTAL		*10,708,000	*17,352,000

* This figure includes Fruit Jars and Jelly Glasses.

Glass container production: Production based on figures released by the Bureau of the Census was 10,708,000 gross during December, 1957. This represents a decrease of 5.8 per cent from the previous month's production of 11,366,000 gross. During December, 1956, glass container production was 10,323,000 gross or 3.7 per cent under the December, 1957 figure. During the year of 1957, glass container manufacturers have produced a preliminary total of 146,297,000 gross. This is 3.3 per cent over the 141,631,000 gross produced during 1956.

Shipments of glass containers during December, 1957 came to 9,494,000 gross, or a decrease of 21.7 per cent from November 1957 shipments which were 12,121,000 gross. Shipments during December, 1956 were 9,712,000 gross or 2.2 per cent above December, 1957. At the end of 1957 shipments have reached a preliminary total of 142,307,000 gross, which is 1.3 per cent over the 140,519,000 gross shipped during 1956.

Stocks on hand at the end of December, 1957 were 17,352,000 gross. This is 7.6 per cent above the 16,128,000 gross on hand at the end of November, 1957 and 24.8 per cent higher than the 13,897,000 gross on hand at the end of December, 1956.

Recent figures released by the Glass Container Manufacturers Institute indicate that glass container shipments in 1957 established a new high level for the third successive year. The figures cover domestic shipments by the 40 manufacturers who are members of GCMI. Their total for 1957 came to 129,635,000 gross, an increase over the 128,833,000 gross shipped in 1956.

Shipments of new glass containers for use in packaging food products, including dairy, totaled 55,965,000 gross last year compared with 55,393,000 gross in 1956, an increase of one per cent. Bottles and jars used in food packaging comprise by far the industry's largest end-use category, about 43 per cent of total shipments.

Gains were also scored in domestic shipments of containers for use in packaging medical and health supplies, in no-deposit soft drink bottles, and in no-deposit beer bottles. Lesser gains were made in shipments of toiletry and cosmetic jars and bottles, and of glass containers for packaging household and industrial chemicals according to the GCMI figures.

New Equipment and Supplies

NEW STURDY HYGROTHERMOGRAPH

Serdex, Inc., 12 Bowdoin Square, Boston 14, Mass., has introduced a new indoor-outdoor hygrothermograph which is said to provide high accuracy humidity and temperature indications for both direct reading and recording.

Hygrometer accuracy, carefully calibrated against laboratory standards, is guaranteed repeatable within ± 3 per cent relative humidity. Operating range is 15 per cent to 95 per cent R. H. at temperatures from 32° F. to 130° F. Correction charts are available for low temperature application. Accuracy of the hygrometer is derived from the use of a specially designed animal membrane diaphragm. The temperature sensitive element of cantilever type bi-metal is guaranteed accurate within ± 1° F. from 0° F. to 100° F.

The model, known as HGS-HYT-1, is an instrument in which the sensitivity, range, and lag of humidity and temperature sensing units are of the same order of magnitude. Easy to read six-inch daily or weekly recording charts are available. The chart drum is actuated by a jeweled clock, manually wound at time of chart change, and precludes loss of record in case of electrical service failure.

RANGE CHANGE FEATURE ON PYROMETERS

The Bristol Company, Waterbury 20, Conn., announces that their potentiometers are now furnished with standardized, readily changeable slidewires and calibration resistors.

The new feature, it is claimed, allows the range on a recorder or controller to be changed quickly and accurately, if the instrument is shifted from one application to another. This interchangeability of circuit components drastically reduces the time needed for modification or repair.

BIN LEVEL INDICATOR

The Bin-Dicator Company, 36 13946 Kercheval Avenue, Detroit 15, Mich., announces new improvements in the company's automatic bin level indicator and control unit. Among these is a twist lock cover which has no nuts or bolts, helpful in units to be installed in difficult locations; a vented housing which relieves any pressure build-up as the diaphragm is flexed in response to the pressure of the material in the bin, silo, hopper or chute; drilled and tapped frames for assembly of cover and diaphragm and diaphragm retainer ring; and a diaphragm assembly which has perforated mounting holes to simplify replacement or change of diaphragm.

DIGITAL CONTROL COMPUTER

The Ramo-Wooldridge Corporation, 5730 Arbor Vitae Street, Los Angeles 45, Cal., has introduced the RW-300 digital control computer, said to be the first digital computer engineered specifically for automatic control of industrial processes, data logging and test stand facility operation. The computer was designed to bring a new degree of automatic control and efficiency to continuous and batch processes. In conventional control of these processes, plant personnel periodically read, analyze, and correlate various instrument readings, then manually adjust the set-points of controllers in order to optimize the process, which can be difficult in many procedures.

In engineering and research applications the computer is said to provide more flexible and more precise test control, immediate recording of data in processed form, and a variety of general computational service.

NEW BASIC WEIGHT CLASSIFIER

Exact Weight Scale Company, Columbus, Ohio has available a new basic weight classifier for process control and classifying of products and packages by weight. The classifier can also be used in production line inspection for missing parts and with open or closed packages for correct contents.

Adjustable crystal photocells are mounted adjacent to the visual dial on the company's Shadograph scale. The photocells provide a precise and reliable electric signal when the pre-set weight limits, or allowable tolerance settings, are reached.

Two or more of the photocells can be mounted across the optical dial of the shadograph Scale to provide any number of classifications from 2 to 128. The larger number of classifications are accomplished with a projected binary coded "gray" scale dial mounted on the weighing mechanism. The photocells are mounted inside the standard housing, and are said to increase the accuracy two times better than the advertised visible sensitivity of the scale.

ONE-PIECE GLASS DOMES

Servo Corporation of America, 20-20 Jericho Turnpike, New Hyde Park, New York, has available one-piece domes made of molded, ground and polished arsenic trisulphide glass. Used in transmitting infrared radiation to infrared detection equipment, the dome shape may be obtained in sizes from 4 to 12 inches in diameter. It can be ordered in any spherical section up to and including 180 or hemisphere.

These domes have withstood high acceleration and sub-zero temperatures without damage. They have a slight negative lens effect (as all concentric shells must) which sometimes can be used effectively as a Maksutov corrector for concentric optical systems.

CATALOGS RECEIVED

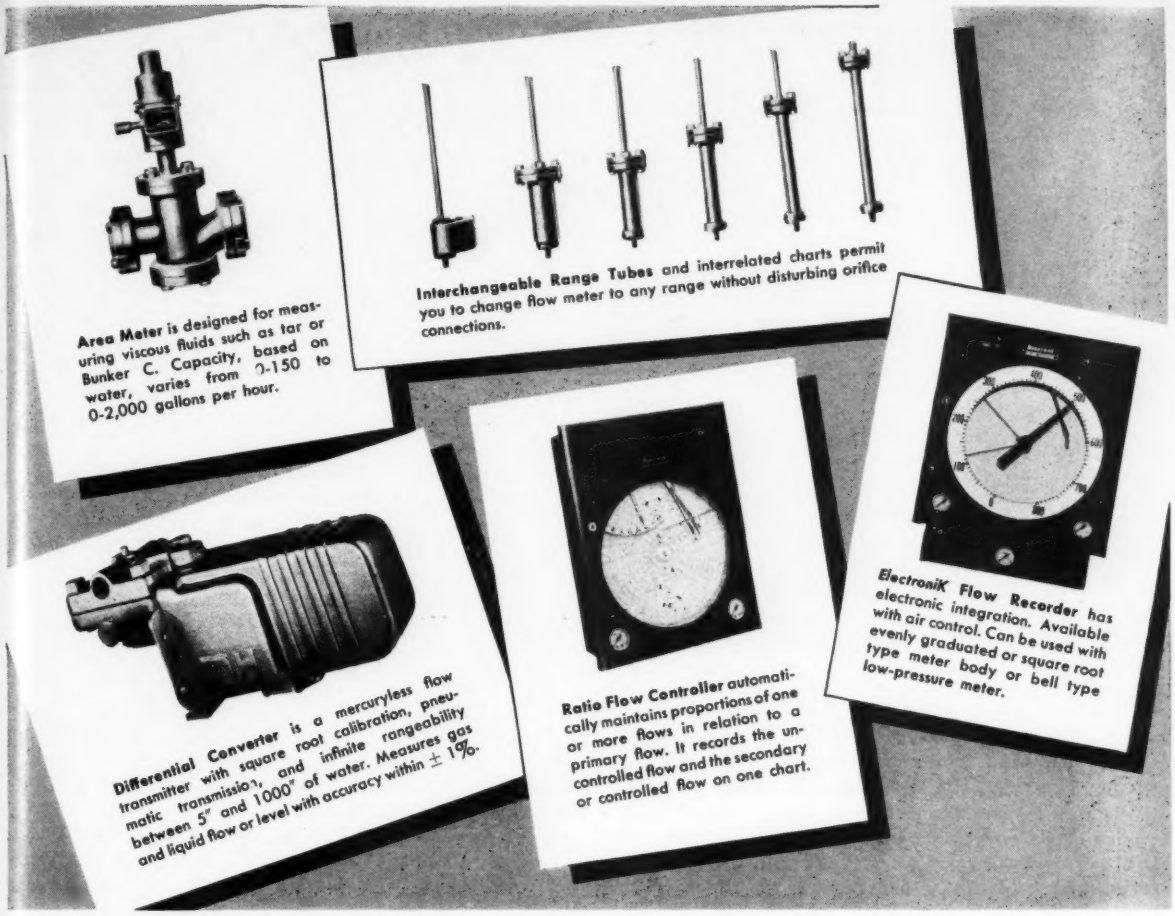
Toledo Engineering Company, 3001 Sylvania Avenue, Toledo 13, Ohio, has issued a 32-page illustrated catalog describing the functions of the company as engineers, designers and contractors. The catalog contains illustrations and some diagrams of furnaces designed and installed for sheet, container, tube and cane, fiber, and special glass furnaces; models of the company's glass batch chargers, burners and lehrs, among other products; examples of fuel oil systems installed; and a section on the machines designed for the lime industry. Write direct to the company.

Manco Products, Inc., 2401 Schaefer Road, Melvindale, Mich. has prepared an illustrated folder outlining the advantages of the company's new Accu-Cast process of precision casting mold and die components direct from expendable original patterns. A panel of production pictures shows typical applications, including molds for forming glass. Properties are listed for components fabricated by the company in a licensed adaptation of the Shaw Process.

Lead Industries Association, 60 East 42nd Street, New York 17, N. Y., has published "Enamels for Application to Glass", the first supplement to the technical data book, "Lead in the Ceramic Industries", distributed early in 1957. It was prepared by Ray Andrews, manager, Glass Colors Division, B. F. Drakenfeld and Company, Inc., Washington, Pa.

The new supplement includes a description of the chemical and physical properties of enamels for application to glass and illustrates how these properties can be controlled by variations in the compositions of the glass fluxes. Ten specific flux formulations are listed with an explanation of the differences between each composition and how these differences have controlled the properties of the flux. Particular reference is made to firing temperature, coefficient of expansion, and acid and alkali resistance.

Copies of the supplement, or of "Lead in the Ceramic Industries" containing the supplement, are available on request to the Association.


Area Meter is designed for measuring viscous fluids such as tar or Bunker C. Capacity, based on water, varies from 0-150 to 0-2,000 gallons per hour.
Interchangeable Range Tubes and interrelated charts permit you to change flow meter to any range without disturbing orifice connections.
Differential Converter is a mercuryless flow transmitter with square root calibration, pneumatic transmission, and infinite rangeability between 5" and 1000" of water. Measures gas and liquid flow or level with accuracy within ± 1%.
Ratio Flow Controller automatically maintains proportions of one or more flows in relation to a primary flow. It records the uncontrolled flow and the secondary or controlled flow on one chart.
ElectroniK Flow Recorder has electronic integration. Available with air control. Can be used with evenly graduated or square root type meter body or bell type low-pressure meter.

Choose the exact features you require . . .

from the complete line of Honeywell flow meters

Why be restricted to one type of flow meter and possibly have to change your process to fit the meter? The completeness of the Honeywell line of flow meters lets you choose the best possible type of meter for any application . . . choose the specific features you need from a wide variety.

You can select either square root or linear calibration . . . mercury or mercuryless or area type manometers . . . pneumatic or electric transmission or mechanically connected instruments. Whether you want to meter air, oil, gas, or most any other fluid, you'll find the exact instrument you need in the Honeywell line—a line unmatched by any other manufacturer.

Your nearby Honeywell field engineer can give you valuable help with your flow metering problems. Call him today . . . he's as near as your phone.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, Wayne and Windrim Avenues, Philadelphia 44, Pa.

Honeywell

H HONEYWELL First in Controls

A. P. GREEN FIRE BRICK APPOINTS A. R. BARNETT AND J. J. OFFUTT

The A. P. Green Fire Brick Company announced the appointment of A. R. Barnett, vice president, as director of A. P. Green Domestic Subsidiaries, including Canada. It was also announced that the board of directors had elected J. J. Offutt a vice president of the company. Mr. Wm. S. Lowe, president, in announcing the election, appointed Mr. Offutt director of sales.

A. R. Barnett J. J. Offutt

Mr. Barnett, who has been connected with the Green Company for approximately 34 years, has served in various executive capacities, including manufacturing, shipping, finance, and sales. Mr. Lowe stated that Mr. Barnett's experience in the operating divisions of the Company places him in a position to be exceptionally well qualified for new responsibility he has assumed as of the first of the year. Mr. Barnett was born in Rich Valley, Indiana. He attended the University of Illinois, later receiving a Master Accounts degree from the Gem City Business College, and completed a one-year extension course from LaSalle University.

Mr. Offutt has been connected with the Green organization for approximately 30 years, first entering its employment in 1928. During this time he has had experience in all phases of the Company's operations, including mining, research laboratory work, sales engineering, sales promotion, plant engineering, and as plant superintendent. In 1946, Mr. Offutt was appointed general manager of the A. P. Green Fire Brick Co., Ltd., Toronto, Canada, and guided it through its most successful growth period, including over 300 per cent increase in the net sales of the company's products. In 1954 he returned to the Mexico Office, taking over various duties in connection with corporate matters of the Company.

ALFRED U. GRANTED $22,000 BY NATIONAL SCIENCE FOUNDATION

A $22,000 grant from the National Science Foundation is enabling Dr. Charles H. Greene, chairman of the Department of Glass Technology at Alfred University, N.Y., to conduct a two-year research program designed to study the strength of glass.

The National Science Foundation, established in 1950, is designed to promote the progress and advance of science in the United States. The grant to Dr. Greene is part of this program.

The complete title of Dr. Greene's project is, "A Study of the Distribution and Nature of Flaws Responsible for the Weakness of Glass". In describing the research program, Dr. Greene said: "The distribution of the residual flaws in acid polished glass will be studied by breaking a sufficient number of samples of various sizes and tests will be made to investigate the directional properties of these flaws. Finally, the way in which flaws are produced by touching or rubbing such acid polished surfaces will be determined."

Dr. Greene emphasized that the weak spots which originate failures in glass are the important and interesting features which must be handled by "a statistical treatment".

Working with Dr. Greene on the project is Robert B. Thomas of Alma, N.Y. He graduated from Alfred University in 1956 as a glass technology major. He was formerly with the National Bureau of Standards in Washington, D.C. Two other research assistants will soon be added to the research staff.

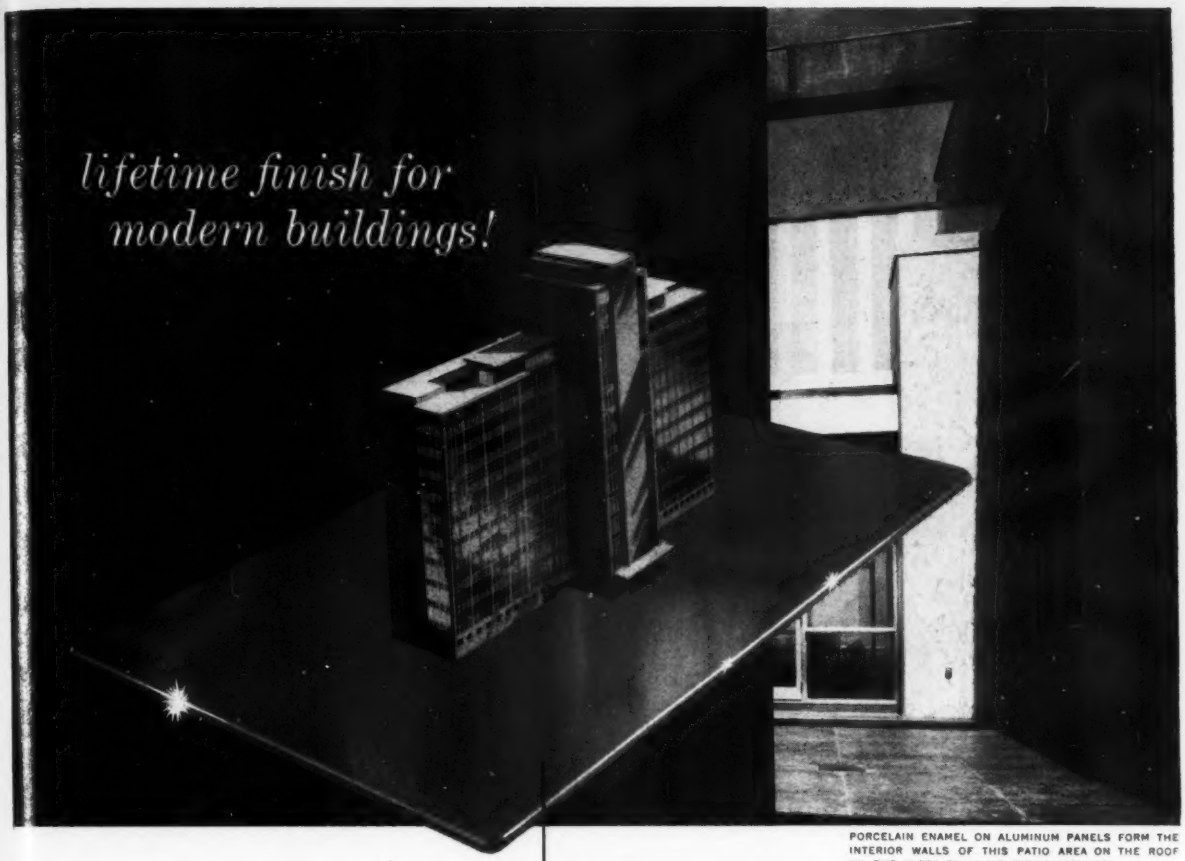
Dr. Greene has been Chairman of the Department of Glass Technology in State University of New York, College of Ceramics, at Alfred University since 1953. A native of Troy, Pa., he is a graduate of Haverford College and received his Ph.D. in physical chemistry from Harvard University.

After a year of work on unusual glass compositions and the strength of glass in the research laboratory of the Corning Glass Works, he served six years on the Harvard University faculty as an instructor in analytical chemistry. He is also a past director of the Byerly Laboratory at Radcliffe College. Dr. Greene returned to Corning Glass Works in 1937 where he served in the research laboratory and the glass technology department. He was manager of the first Corning pilot plant and later named manager of melting development.

PACIFIC COAST BORAX APPOINTS THREE VICE PRESIDENTS

R. W. Hinchman M. H. Pickard

Pacific Coast Borax Company Division of United States Borax & Chemical Corporation has announced the appointment of three divisional vice presidents. They are: L. L. Fusby, vice president—production; R. W. Hinchman, vice president—sales; and M. H. Pickard, vice president—market research and product development. Mr. Hinchman and Mr. Pickard will continue to make their headquarters in New York and Mr. Fusby will continue at Los Angeles, according to J. F. Corkill, vice president and general manager.



PORCELAIN ENAMEL ON ALUMINUM PANELS FORM THE INTERIOR WALLS OF THIS PATIO AREA ON THE ROOF OF THE ALCOA BUILDING, PITTSBURGH, PA.

Trona® Lithium Carbonate

helps make ARCHITECTURAL PORCELAIN ENAMEL hard and beautiful as glass – strong as the base metal

The lifetime finish of porcelain enamel makes it a versatile modern architectural material. Used as a tough, ceramic coating for architectural aluminum, porcelain enamel enables architects and engineers to take full advantage of the lightweight metal for dramatic structural and decorative purposes. It enhances color appeal, durability and ease of fabrication.

TRONA® Lithium Carbonate is used in the manufacture of commercial frit for ceramic coatings. It is a powerful fluxing agent, permitting the frit to melt at lower temperatures and contributing to improved adherence of the coating to the base metal. Li_2CO_3 is an important member of the family of TRONA chemicals designed always to provide the right beginning for end-product quality.

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Three Elephant®
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Milestones in Glass Progress

PHOTO COURTESY CORNING GLASS WORKS

1939 Called the most revolutionary glass in 4000 years, Vycor brand glass is extremely tough, made from 96% silica. It withstands violent changes from hot to cold without injury (above: pouring molten metal inside while resting on ice). Developed in 1939, Vycor is used in laboratory equipment, sun and germicidal lamps.

1890 Michigan Alkali Company, now a division of Wyandotte Chemicals Corporation, was founded by Captain I. B. Ford to supply Soda Ash to the glass industry. At Wyandotte, there is no compromise with quality — insured by rigid tests from arrival of limestone at our docks (above), to final delivery of Soda Ash. Another reason why Wyandotte is a dependable source of raw-material chemicals for glassmakers.

Wyandotte CHEMICALS

Michigan Alkali Division, Wyandotte Chemicals Corporation
Wyandotte, Michigan • Offices in principal cities

Founded by a Glassmaker to Serve the Glass Industry

Glass: Its Transparency . . .
(*Continued from page* 89)

4.6. Properties versus Types of Bonds

A good summary of properties versus types of bonds, given by Hauth (Reference 10) and supplemented by the present writer, is shown in Table 2.

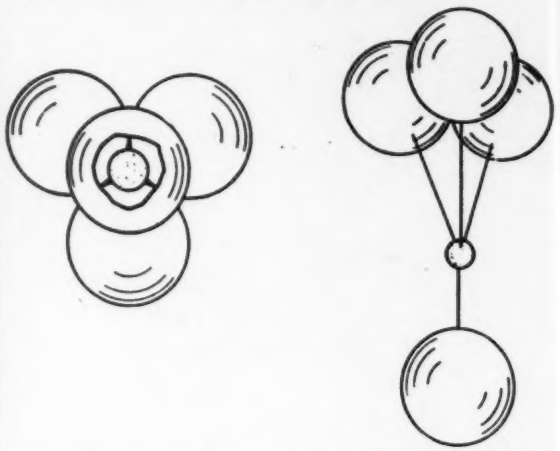

Fig. 9. The basic SiO_4 structure, showing coordination of of four. On the left it is expanded and on the right a cut-away view is shown. Sizes are drawn to scale. (Ref. 10)

Bonding in Relation to Transparency

Perfect crystals of an ionic or covalent nature with bound electrons can be transparent because of lack of interaction with the electromagnetic light wave. On the other hand, crystals which carry many electrons which are free to change location—like metallic bonds—are opaque because such electrons interact with and influence light waves. These interactions are the result of electrical interference between waves and particles, each of which has electromagnetic properties.

APPENDICES

Appendix 1

Units and Decimal Points

Å = Angstrom Unit = .00000001 cm. or 10^{-8} cm
μ = micron = .0001 cm. or 10^{-4} cm.

1 cm. = 1 x 10^0 cm.)
10 " = 1 x 10^1 cm.)
100 " = 1 x 10^2 cm.)
1000 " = 1 x 10^3 cm.)
} Take 1 and point off to the right with number of places of superfix.

0.1 cm. = 1 x 10^{-1} cm.)
0.01 cm. = 1 x 10^{-2} cm.)
0.001 cm. = 1 x 10^{-3} cm.)
} Same as above except point off to the left.

Appendix 2.

Electromagnetic Radiation

The physicist uses two inter-related concepts in his explanations of the properties of matter—waves and particles.

Waves

The electromagnetic radiations consist of a series of inter-related phenomena which can most easily be understood by considering them as radiations having certain wave lengths (Table 3). The series includes cosmic rays, gamma rays,

(*Continued on page* 112)

"The used key is always bright"

Benjamin Franklin...1706-1780... "Poor Richards Almanac

Several centuries after being written, many of the famous quotations from Ben Franklin's "Poor Richards Almanac" are used in everyday conversation, and they will be used to "strike home" a point in eras to come. Each particular phrase has a true philosophic meaning and in this particular example it is the lesson of "the more use — the most value".

Such is the case today in everyday business practice. No one has faith in a product until it has proven its worth and is in constant demand . . . and an excellent example of "a used key" in today's glass production is O. HOMMEL GLASS COLORS . . . the "bright key" in the industry everywhere.

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Glass: Its Transparency . . .

(*Continued from page* 110)

X rays, ultraviolet light, visible light, infrared radiation, and thence on through to radio waves, electric waves, etc. These all show a wave nature and are characterized by a common speed in a vacuum. This speed is the speed of light. For instance, a radio wave sent out from New York travels across the country at the speed of light.

A wave motion does not necessarily involve a transfer of mass. When one throws a stone into a pond, we have waves traveling out away from the point of entry in all directions. However, when one puts a cork on the surface of the water at a slight distance from the source, it is not moved out with the wave. The action is one of an up-and-down movement of the water surface, with no outward motion. That is, the up-and-down motion of the water gives a wave motion outward, or at right angles to the up-and-down motion. Here the speed of the wave outward is, of course, slow and its intensity decreases greatly as the distance from the source increases. The wave length is the distance from one crest to the nearest neighbor crest. This wave length is at most a few inches.

When a radio wave is sent out, it travels at the speed of light. As given in Table 3, a typical wave length would be between 10,000 and 100,000 cm.[1], or say 50,000 cm. Since its speed is that of light, or 3×10^{10} cm. per second, we find that its frequency, in number of cycles per second, must be:

$$\text{Frequency in cycles/second} = \frac{3 \times 10^{10} \text{ cm./sec.}}{50{,}000 \text{ cm.}}$$

$$\text{Frequency} = 600{,}000 \text{ cycles per second}$$

$$\text{Frequency} = 600 \text{ kilocycles}$$

or the usual 60 or 600 on the radio dial. This relationship for all electromagnetic waves,

$$\text{Frequency} = \frac{\text{Speed of Light}}{\text{Wave Length}}$$

(given in lower right-hand corner of Table 3) is a fundamental one and gives a common basis for such waves; that is, the speed of light.

Since all electromagnetic radiations (partially listed on left side of Table 3) possess the speed of light, they differ only in having different wave lengths. Thus the wave theory is based on a uniform concept of wave motion, with the wave length being the fundamental unit of difference. Such a concept is useful particularly in the realm of the longer wave lengths.

[1] See Appendix 1 for use of units and superscripts.

The entire electromagnetic radiation spectrum is a continuous, overlapping series. We have illustrated only portions in Table 3.

Particles

The second concept of use for analysis of properties of matter is one involving particles. When the wave lengths get very short, such as in X rays (see Table 3), the frequency gets very great and the concept of waves becomes less useful. The physicist has been able to "track" the paths of certain "particles" which he produces by electromagnetic means. Such "paths" are made visible by a number of different procedures, one of which, for instance, involves a streak of light, or perhaps an electrical effect. A number of so-called fundamental "particles" has been built up as a concept of the fundamental nature of matter. These particles often will act in fashions quite consistent with the wave theory. Of course, they have mass and the velocities are consistent with the transfer of mass. For instance, the electron, which is the unit charge of negative electricity, can be made to create a path. Electrons from the gun of a television tube race to the face of the tube to create light at the position where they touch the surface of fluorescence.

Thus, when we speak of waves and particles, we must agree that

Waves have particle characteristics, and
particles have wave characteristics.

Units of Energy

One other concept is necessary. If the concept of particles is accepted, then these particle units under vibration represent units of energy. All energy must be a multiple of the smallest known energy unit. This is similar to building up a car storage battery. Each cell represents 2 volts. Batteries are made up of three cells or a total of 6 volts. A battery of 7 volts cannot be assembled from a whole number of 2-volt cells. Using the same reasoning, the unit of negative electricity is 1 electron. All electrical energy must consist of multiples of whole electrons.

This same thing is true of light. In the photoelectric cell we receive light energy on the cell face, which by proper chemical action converts the light to electrical energy. This later moves the needle of the meter. There is thus a fundamental unit of light as well as a fundamental wave motion.

The Quantum Theory

This entire concept, when carried through all the associated mathematics, is known as the "quantum" theory and the units of energy are termed "quanta." These units become larger as the frequency increases. The end of the electromagnetic spectrum associated with short wave lengths (left top of Table 3) represents the end where the "quanta" are composed of the larger chunks of energy. Particle effects were first noted in this end of the spectrum and this end covers the early discovered radioactive effects. This is the end of massive penetration of solids by particles because the particles have great energy.

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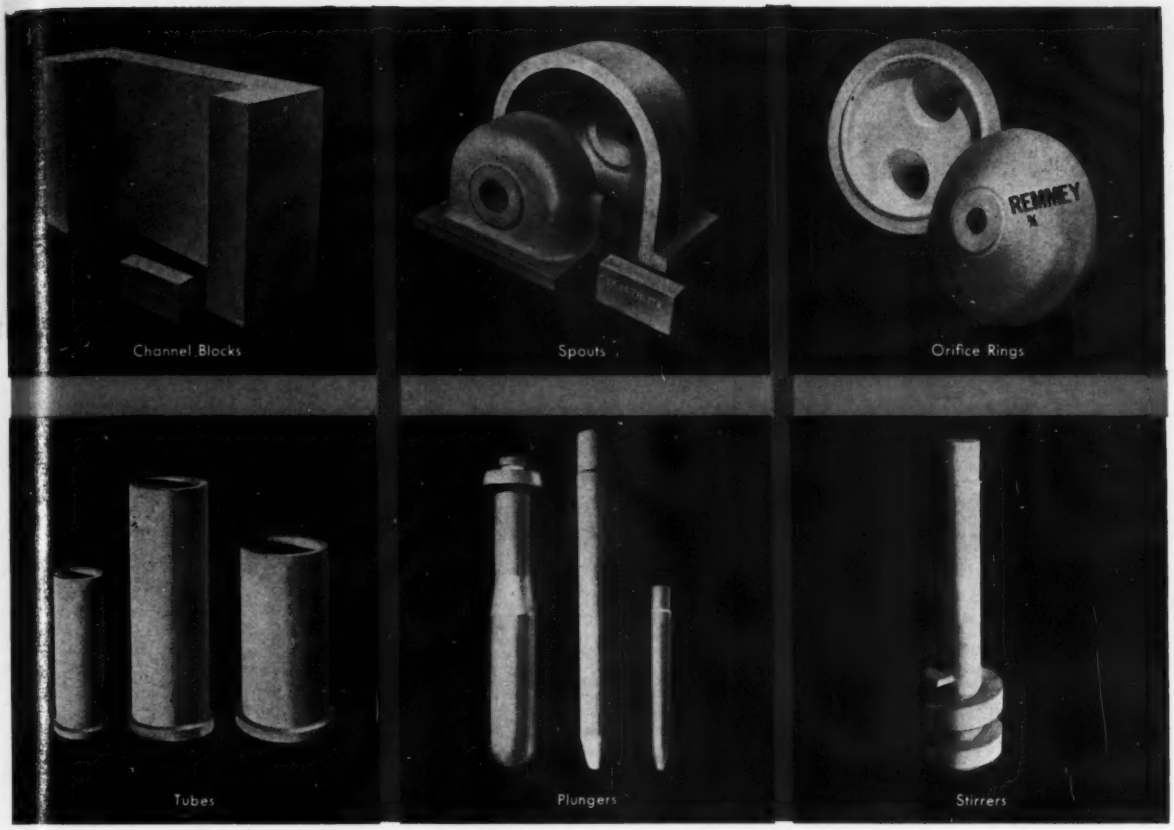
(*Continued on page* 114)



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Glass: Its Transparency . . .

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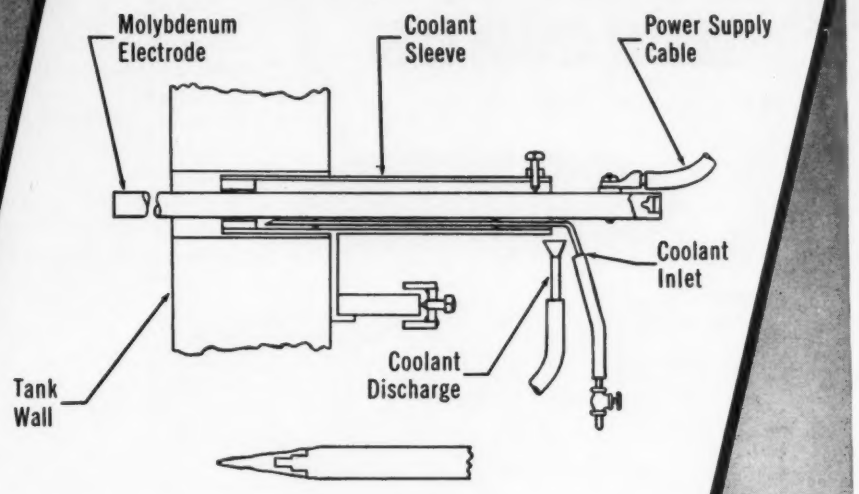

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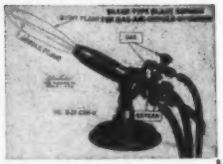

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Inventions . . .

(*Continued from page* 102)

act as a binder, the resin must of course be appropriately cured. The depressions are preferably completely filled to provide a flat planar surface which can be easily cleaned. Alternately the coloring material may be dispersed in an easily fusible ceramic material such as a powdered glaze or enamel, the depressions filled with such mixture, and the glass body subsequently fired to fuse the ceramic carrier. Care must be taken, however, to secure a proper expansion match of the ceramic with the glass.

While the etched-out portions of the strips may, according to the preferred embodiment of the invention, be removed by solution with dilute aqueous hydrofluoric acid, they may also, if desired, be removed by grinding, in which case the photo-sensitively opacifiable glasses described in Patent No. 2,515,941 may also be utilized.

There were 3 claims and the following references were cited in this patent: 1,244,734, Higgins, Oct. 30, 1917; 1,494,630, Reizenstein, May 20, 1924; 2,053,173, Astima, Sept. 1, 1936; 2,515,940, Stookey, July 18, 1950; 2,515,943, Stookey, July 18, 1950; 2,628,160, Stookey, Feb. 10, 1953; and 458,509, Great Britain, Dec. 14, 1935.

Making Glass Filters. Patent No. 2,752,731. Filed January 6, 1953. Issued July 3, 1956. Two pages drawings; none reproduced. Assigned to Dominion Textile Co. Ltd. by Helno Altosaar.

The invention is a method of making a glass filter which comprises the steps of threading a metal wire through a glass capillary, heating and drawing the glass capillary over the wire so as to reduce the diameter of the glass capillary while increasing its length, cutting the glass coated wire into lengths, confining the glass coated wire lengths in a predetermined pattern and in juxtaposed axial alignment and fusing the lengths into a homogeneous mass and finally removing the wire cores by immersion of the homogeneous mass in an acid bath.

The glass covered wire is cut into lengths considerably greater than the desired thickness of the filter and after fusing is sliced into portions of the desired thickness of the filter before the wire cores are removed.

Filters may be made by this method of any desired size and with any desired number of holes having any desired diameter. The only limitation to the size of holes is determined by the gauge of the wire used as the metallic core. For example, wire may be used running from the heaviest gauge down to the finest commercially available.

There were 8 claims and the following references cited: 2,143,907, Blumlein et al., Jan. 17, 1939; 2,306,986, Tolman, Dec. 29, 1942; 2,328,302, Simison, Aug. 31, 1943; 2,354,931, Tolman, Aug. 1, 1944; 2,433,271, Grant, Dec. 23, 1947; and 507,711, France, July 2, 1920.

Opthalmic Lenses. Patent No. 2,755,706. Filed April 18, 1952. Issued July 24, 1956. One page drawings; none reproduced. Assigned to American Optical Company by Thomas Russell Cole.

This invention relates to improvements in opthalmic lenses and has particular reference to an improved mul-

(*Continued on page* 118)

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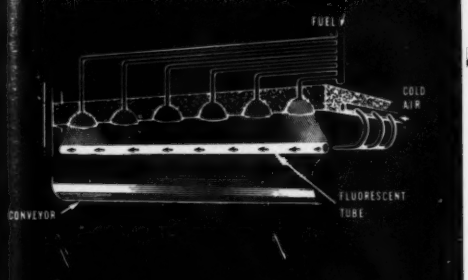

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Heat and Fluid Processing Engineers
DEVELOPMENT • DESIGN • CONSTRUCTION

Inventions . . .

(*Continued from page* 116)

tifocal lens and method of making the same.

A multifocal lens is provided having a major distance field, a relatively long and narrow field of intermediate power lying within the distance field and extending in a direction transversely of the vertical center line of the lens. The intermediate field has clifflike upper and lower edges, knifelike end edges and an exposed front surface flush with the front surface of the distance field; a segment is embedded within the glass of the major distance field with its upper edge relatively thick and in engagement with the lower edge of the intermediate field; the remainder of its contour has a knifelike edge. The lens thus has three major focal fields of different powers for the correction of distance, intermediate and reading vision.

There were 4 claims and the following references were cited in this patent: 1,866,734, Tillyer, July 12, 1932; 2,033,573, Hancock, Mar. 10, 1936; 2,035,846, Sterling, Mar. 31, 1936; 2,053,551, Culver et al., Sept. 8, 1936; 2,071,616, Culver et al., Feb. 23, 1937; 2,173,651, Hill, Sept. 19, 1939; 2,177,022, Hammon, Oct. 24, 1939; and 2,274,143, Houchin, Feb. 24, 1942.

Glass Laminate Containing Transparent Filler. Patent No. 2,756,171. Filed July 31, 1952. Issued July 24, 1956. No drawings. Assigned to Bjorksten Research Laboratories, Inc. by Frederick L. Thomas.

This invention relates to safety glass laminates and particularly to such laminates which are suitable for use at high temperatures and comprise alkyl siloxanes.

A heat resistant siloxane polymer is molded at 105°C. to 300°C. together with a free radical type catalyst such as, for example, benzoyl peroxide, di-tertiary butyl peroxide, acetyl peroxide, hydrogen peroxide, or sodium peroxide and a substance having an average particle size of about 20 microns or less, a refractive index (n_D^{25}) of 1.39 to 1.46 and having a cubic crystal lattice structure isotropic to light in the visible spectrum.

The product is both highly transparent and is resistant to high temperatures. It does not decompose or become substantially deformed at 500°F. As an example, 2.5 parts of benzoyl peroxide and 45 parts of potassium cyanide which had an average particle size of about 15 microns were mixed intimately with 100 parts by weight of dimethyl polysiloxane polymer which had a viscosity of greater than 2,000,000 centipoises and which had been washed free of any acid. The resulting doughy mass was pressed into a sheet between sheets of aluminum foil under hydraulic pressure and at a temperature of 105°C. A flexible, tough transparent film results, which is resistant to high temperature.

There were three claims and the following references were cited in this patent: 2,304,754, Wainer, Dec. 8, 1942; 2,389,491, Dunlap, Nov. 20, 1945; 2,502,286, Sowa, Mar. 28, 1950; 2,504,388, Braley, Apr. 18, 1950; 2,541,137, Warrick, Feb. 13, 1951; 2,596,085, Wormuth, May 6, 1952; and 2,601,337, Smith-Johnnsen, June 24, 1952.

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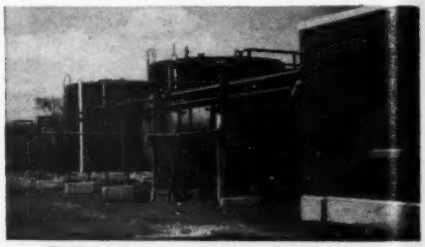
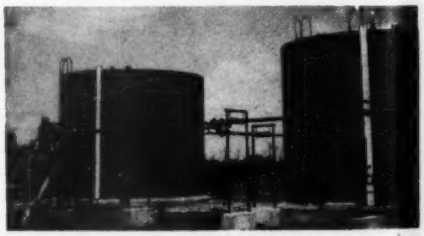


Bulk storage tanks, circulating tanks and pump house, all TECO engineered.



Bulk storage tanks with interconnecting, unloading and transfer lines.

Shutdowns due to curtailment of natural gas have proved costly to many manufacturers in the past.

On the other hand, glass melting plants where precautionary wisdom has been exercised are no longer plagued with fuel supply problems.

★ TECO can design the complete system from bulk unloading station, up to the oil burner on the furnace.

★ TECO designed systems have been installed in some of the largest glass plants in the country.

Write or Phone FOR FURTHER INFORMATION

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DESIGNERS & BUILDERS OF GLASS MELTING FURNACES

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Decorated glassware emerges from lehr and is inspected by technician. Firing temperature: 1,100° to 1,250° F.

DU PONT GLASS COLORS go on laboratory firing line to assure you of highest quality

After thorough testing during every step of manufacture, Du Pont Glass Colors are fired on glassware in a laboratory lehr. This conclusive performance check assures you of the uniformity and high quality of each color.

Du Pont Glass and Ceramic Colors are stable over a wide firing range, economical to use, easy to apply. A complete line is available from Du Pont, together with in-plant technical help and research assistance in selecting acid-, alkali- and sulfide-resistant colors for glass . . . squeegee oils and metallic decorations . . . conductive silvers, and porcelain enamels for aluminum. Call our nearest District Office for details or write Du Pont at the address below.

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GLASS ENGINEER

Opportunity for competent graduate engineer with at least five years experience in technical or research work in the glass industry. Immediate function is to provide continuity in several product development projects. Long range potential in top technical management. Write Penberthy Electromelt Company, 4301 Sixth Avenue So., Seattle 8, Washington.

GLASS COLOR TECHNOLOGIST

EXCELLENT OPPORTUNITY FOR CERAMIC ENGINEER OR GLASS COLOR TECHNOLOGIST

Must have experience in development, manufacturing and application of glass colors to glass containers.

Excellent Salary, Fringe Benefit Program, and Future. Must be able to travel.

All replies confidential. Please state qualifications and experience. Box 209, The Glass Industry, 55 West 42nd Street, New York 36, N. Y.

MANUFACTURER'S REPRESENTATIVES for large tempered glass manufacturer. We want representatives who are now covering related glass items and architects. Include in first letter territory you now cover, lines carried, and a brief resume of your experience and operation. Box 210, The Glass Industry, 55 West 42nd Street, New York 36, N. Y.

GLASS COLOR TECHNOLOGIST

SPLENDID OPPORTUNITY FOR TECHNOLOGIST OR CERAMIC ENGINEER

Must have experience in development and manufacture of glass colors. Excellent salary and future. Pension benefits after 3 years, group life plan and family hospitalization. You will represent a top supplier with East Coast headquarters. Please state qualifications experience and salary requirements in your reply, which will be kept confidential. Box 211, The Glass Industry, 55 West 42nd Street, New York 36, N. Y.

PLANT MANAGER

ASSISTANT PLANT MANAGER

Glass Container Plant

Plant Manager or Assistant Plant Manager for medium size glass container plant on Pacific Coast. Must have knowledge and experience in all phases of plant management and operation. An excellent opportunity for advancement in an expanding multi-plant division of a nation wide integrated corporation. Send resume of experience and qualifications to Box 212, The Glass Industry, 55 West 42nd Street, New York 36, N. Y.

MACHINERY WANTED

WANTED: Used PBS or MPS Lynch Press with moulds and spare parts set, in very good condition. Reply to Box 213, The Glass Industry, 55 West 42nd Street, New York 36, N. Y.

R. E. DEETZ IS PLANT MANAGER

Anchor Hocking Glass Corporation announces the promotion of R. E. Deetz to plant manager of the company's Jacksonville, Florida glass container factory. Mr. Deetz has been with Anchor Hocking 26 years, starting at Lancaster, Ohio plant number 1 in 1931. He became a general foreman, then acting department head. In 1949 he was promoted to special assignments, working out of the general offices of the company at Lancaster. In 1951 he was named assistant plant manager of Anchor Hocking's plant number 5 at Connellsville, Pennsylvania. Mr. Deetz was transferred to the Jacksonville plant in 1956, in charge of quality control. J. H. Nogar, Sr. is the assistant plant manager at the Jacksonville plant of Anchor Hocking.

ROBERT G. KING, VITRO, DIES

Funeral services were held January 4 in Grove City, Pa., for Robert G. King, 39, assistant general manager of Vitro Manufacturing Company, Pittsburgh, Pa., who died January 1 in Grove City Hospital.

Mr. King, a World War II veteran, joined the Vitro sales department in 1946 after discharge from the Army Medical Corps. He was named sales manager in 1950 and became assistant general manager in 1957.

Our Sales Strategy — sell only the finest silica products in the world

OTTAWA SILICA SANDS

THE WORLD'S FINEST SILICA SAND

99.89% PURE

OTTAWA SILICA COMPANY

PLANTS LOCATED IN OTTAWA, ILL. AND ROCKWOOD, MICH.

SERVING THE FOUNDRY, GLASS AND CERAMIC INDUSTRIES FOR OVER 50 YEARS

What is needed to produce uniform quality in ALL glass?

Whatever type glass you produce, your product always requires quality materials and the know-how that is so essential for the profitable production of a saleable product.

The continued leadership of SOLVAY Soda Ash in the glassmaking industry is based on the same two factors—a product that continues to set industry quality standards, plus a specialized Glass Technical Service with knowledge and practical experience acquired during the 75 years we have been closely associated with the glass industry.

In addition, SOLVAY local sales representatives are always available—from 13 widely situated branch offices—to provide the extra services that the SOLVAY trademark has come to represent to soda ash users in the glass industry.

SOLVAY Chemicals for Glassmaking

Soda Ash
Potassium Carbonate
Ammonium Bicarbonate
Sodium Nitrite

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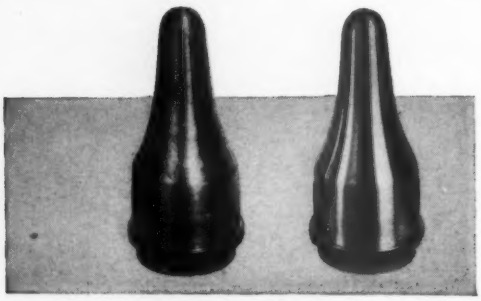
Vinyl Chloride • Mutual Chromium Chemicals • Para-dichlorobenzene • Ammonium Chloride • Aluminum Chloride • Carbon Tetrachloride
Methylene Chloride • Hydrogen Peroxide

THERMOSPRAY coated mold plungers give 8 times longer service life

Important savings are being made in production down-time and replacement-part costs on equipment subject to heat and abrasion. Typical of these are mold plungers like those shown here which are being THERMOSPRAY coated by glass manufacturers for protection against heat corrosion. Other advantages include improved product quality, with better finish on glass parts. Longer production runs are feasible without dismantling machines.



Before (left) and after (right) coating with METCO *ThermoSpray* Process. Users report coated plungers last average of 8 times longer than uncoated. Parts finish is improved, production down-time reduced.

The new METCO THERMOSPRAY Process consists of spraying specially developed alloys in powder form with the METCO THERMOSPRAY GUN. These alloys are of the nickel-chrome-boron type and are self-fluxing. No compressed air is required. Coating hardnesses range from Rc 30 (machineable) to Rc 65, depending on the specific THERMOSPRAY alloy used; will even outwear hardened steels from 3 to 10 times. Spraying speeds are higher – 8 to 10 lbs. per hour – and deposit efficiency far greater (up to 97%) – than with any other type of available equipment.

Application of these materials in powder form permits close control of the amount applied and leaves a comparatively smooth surface that requires a minimum of finishing compared to other methods of application.

Free bulletin—write today for Bulletin 126 which illustrates and describes the METCO ThermoSpray Process or ask for a call by a full-time, company-trained Metco Field Engineer in your territory.

The following names are the property of Metallizing Engineering Co., Inc.: METCO, ThermoSpray.*

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METALLIZING EQUIPMENT COMPANY, LTD.—Chobham near Woking, England

J. E. ARBERRY, PITTSBURGH PLATE, DIES

James E. Arberry, 57, associate chief engineer for Pittsburgh Plate Glass Company's glass division, died November 29 at Magee Hospital in Pittsburgh. His residence was at 652 Pennridge Road, Pittsburgh. A native of Plymouth, England, Mr. Arberry was a graduate of the Royal Naval Engineering College at Plymouth and Dartmouth, England. He graduated as a sub-lieutenant in the Royal Navy in 1922.

He joined the Pittsburgh Plate Glass Company at Creighton, Pa. as an electrician in 1926, later served as electrical engineer at the company's Henryetta, Oklahoma, plant. He was assigned to the engineering department at the company's general offices at Pittsburgh in 1935 and later served as chief electrical engineer and as assistant chief engineer. He was advanced to the position of associate chief engineer earlier this year.

Author of numerous articles on the use of electricity by the flat glass industry, Mr. Arberry was a member of several engineering societies.

KIMBLE NAMES SERVICES DIRECTOR

Roy C. Kendall has been named director of technical services for the Industrial Materials Division of Kimble Glass Company, an Owens-Illinois Glass Company subsidiary. In announcing the appointment, E. P. Lockart, vice-president and general manager of the Division, said Mr. Kendall will establish headquarters at the firm's Muncie, Indiana, plant, and will report directly to the Muncie plant manager, Edward P. Spence.

BOOK REVIEW

X-ray Crystal Structure. By Dan McLachlan, Jr., Stanford Research Institute. 340 pages, 6 x 9, illustrated. McGraw-Hill. $15.00

Many books have been written in a popular style emphasizing the importance of x-ray crystallography and a few (more rigorously) for the benefit of the advanced scholar. This book is designed to fill the gap between the popular and rigorous treatment.

X-ray Crystal Structure gives a logical modern picture of the advanced phases of crystal structure analysis by x-ray methods; and at the same time supplies the reader with the work of the pioneers of crystallography in condensed form.

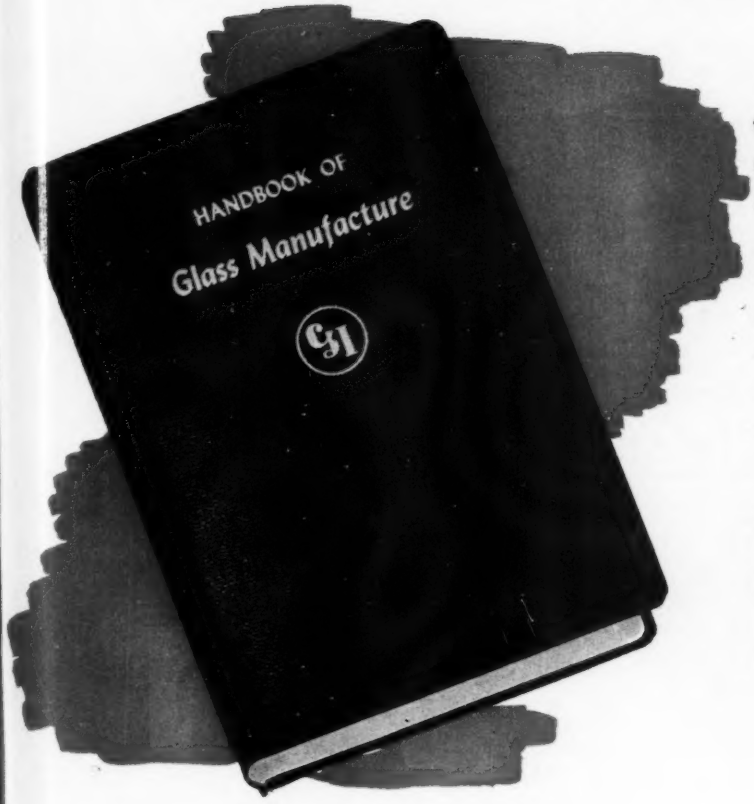
The book tells how to determine the atomic positions within a crystalline material, using the x-ray data obtained from single crystals. It stresses the theory of space groups, single crystal cameras, Fourier methods, the phase problem, computing devices, and the derivation of the point groups; and combines theoretical background with practical applications.

The author's long experience in industrial chemistry includes work for the Sinclair Refining Company, the Corning Glass Works, the Stamford Laboratories of the American Cyanamid Company, and the Stanford Research Institute where he is now Assistant Director of the Poulter Laboratories.

Further details may be obtained from McGraw-Hill Book Information Service, 327 W. 41st Street, New York 36.

Again available

Handbook of Glass Manufacture



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Just three years ago the *new* HANDBOOK OF GLASS MANUFACTURE was offered to the glass manufacturing industry and eighteen months after publication the entire edition was sold out.

Without interruption the demand for copies of the Handbook has continued and it is for this reason that we decided to bring out a second edition of the book. This second printing, identical in content, format and binding, is now available.

The continued demand for the HANDBOOK OF GLASS MANUFACTURE proves that it has filled an important role as a practical working tool for *glass plant executives, research heads, laboratory technicians, engineers and technologists.*

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